METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 63 No. 378 APRIL, 1961 Monthly: Two Shillings and Sixpence

HALE

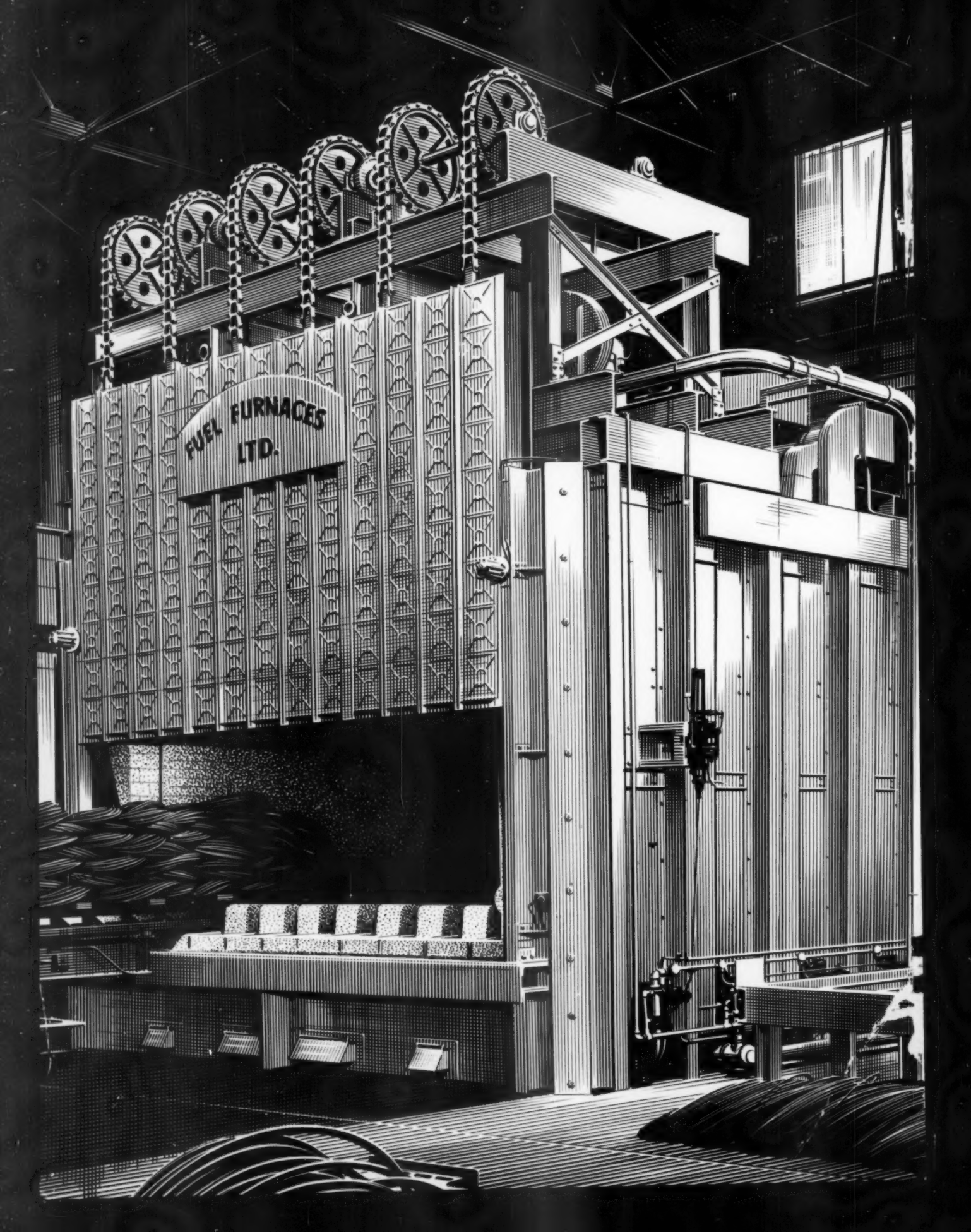
Malleable Iron

CASTINGS

Specified by the leading Industries in Great Britain

HALE & HALE [TIPTON] LIMITED DUDLEY PORT Staffs

GRAMS: 'HALEFO' TIPTON. PHONES: TIPTON 1671/5


FUEL FURNACES
LTD.

Protectoglo

is the only combustion safeguard relay which can be used with every known rectification type of sensor: electrode, photocell, infra-red, ultra-violet . . . Whatever the type, Protectoglo gives you, in a single box, the basis of a wide variety of safety systems. It provides automatic cut-off on flame failure, push-button reset purge timing. Protectoglo has a fully plug-in chassis and a self-checking circuit to prevent start-up in the unlikely event of a faulty component.

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I am interested in PROTECTOGLO—your new combustion safeguard relay.

Please send
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Position .....

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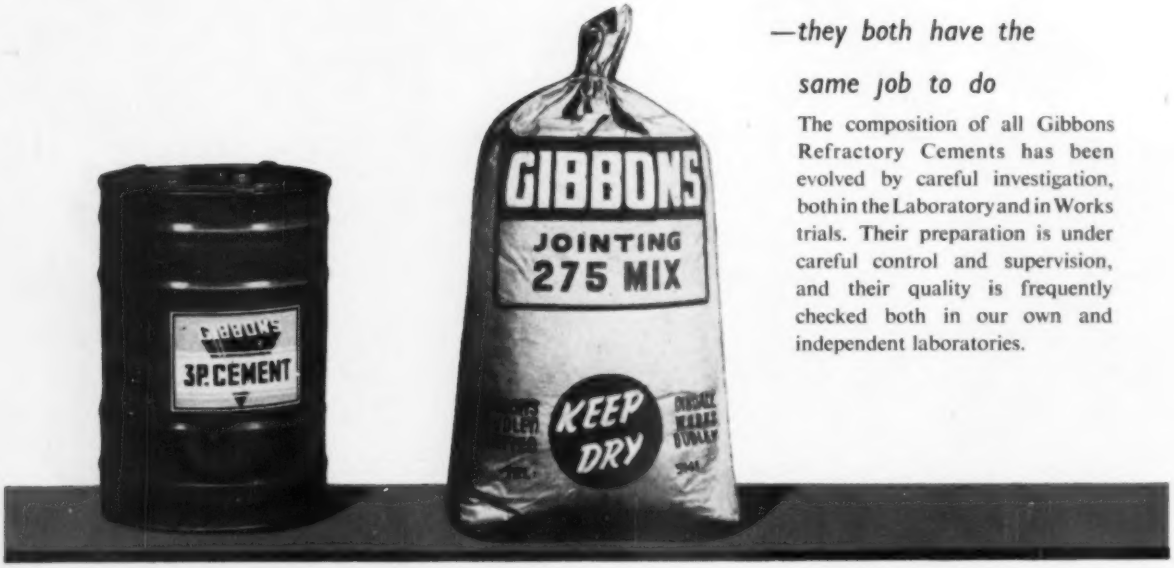
Sales Offices in the principal towns and cities in the United Kingdom and throughout the world.

Honeywell

First in Control

SINCE 1885

Choose your Refractory Cements as carefully as you choose your bricks



—they both have the same job to do

The composition of all Gibbons Refractory Cements has been evolved by careful investigation, both in the Laboratory and in Works trials. Their preparation is under careful control and supervision, and their quality is frequently checked both in our own and independent laboratories.

GIBBONS

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Refractory and Insulating Refractory Concretes · Firebrick and Insulating Firebrick Aggregates

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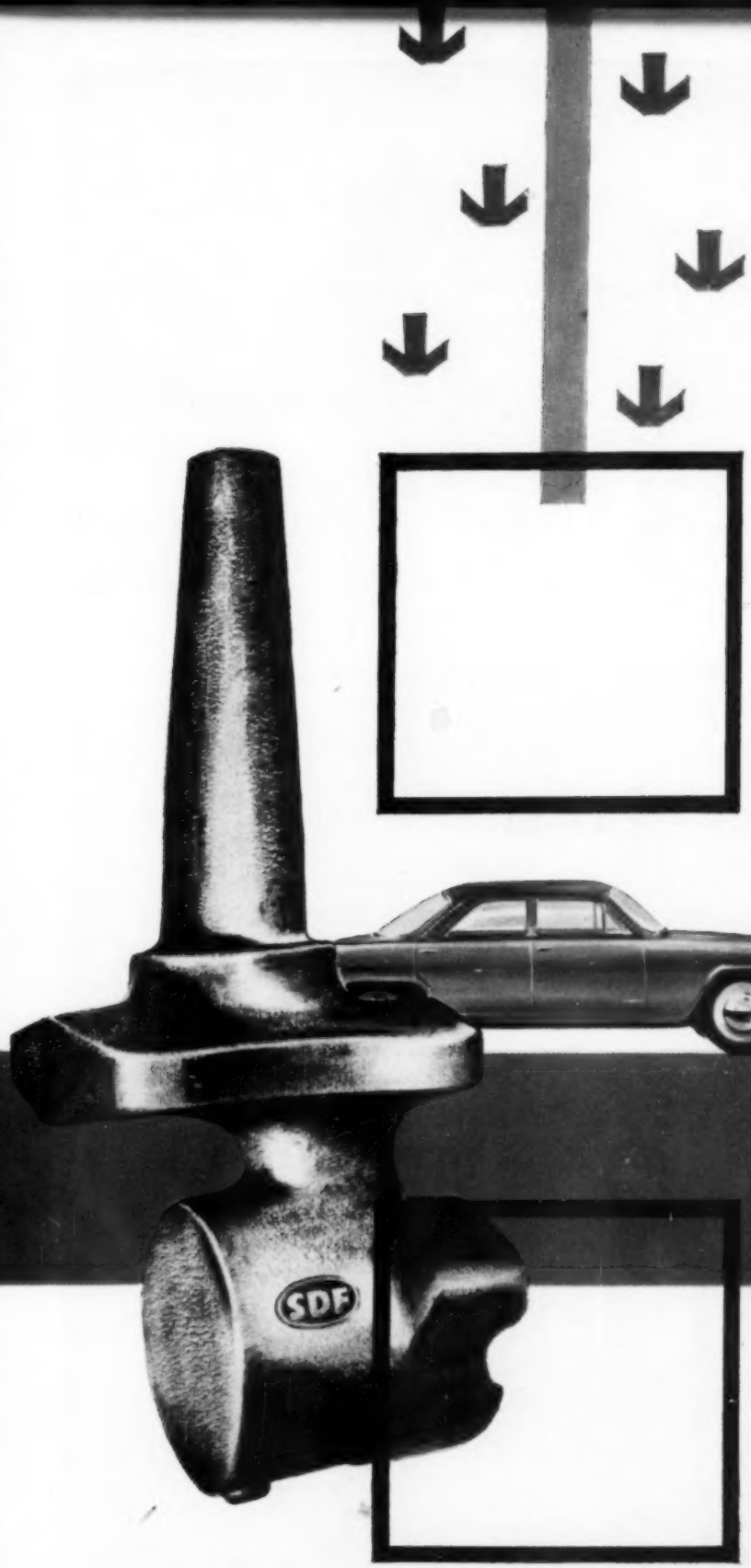

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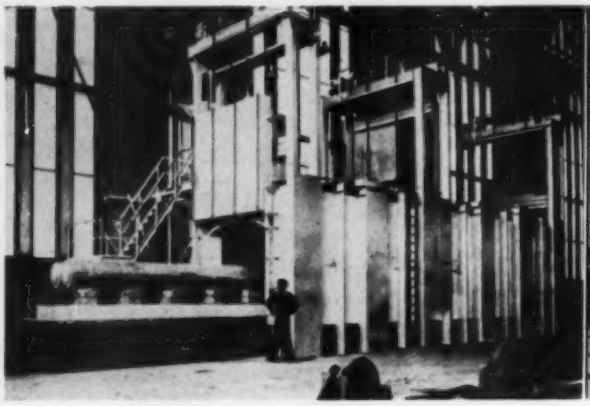
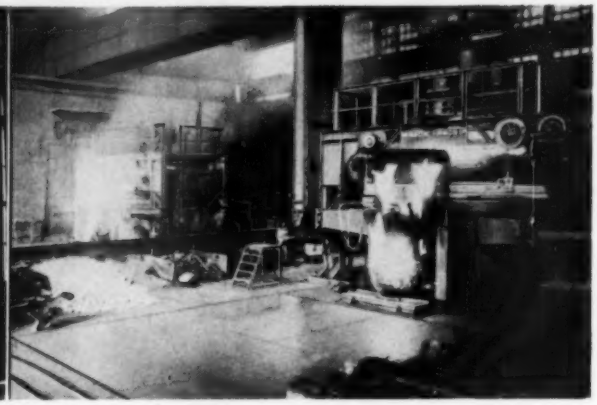


150 ton capacity bogie hearth furnace



80 ton direct arc melting installation

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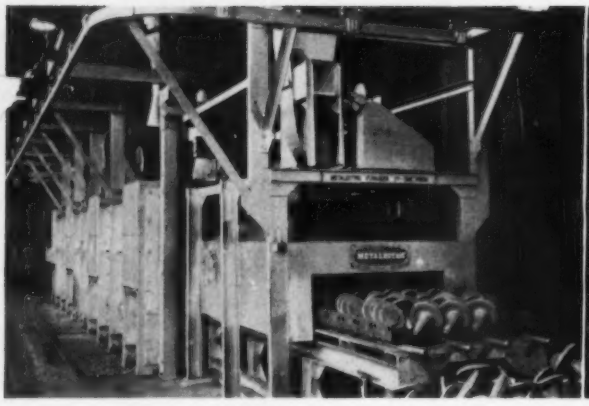
HEAVY DUTY ELECTRIC FURNACES SERVING INDUSTRY EVERYWHERE



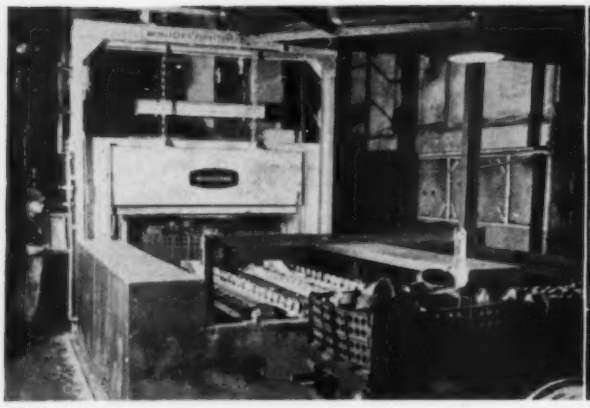
Continuous normalizing of forgings

Continuous hardening and tempering of forgings

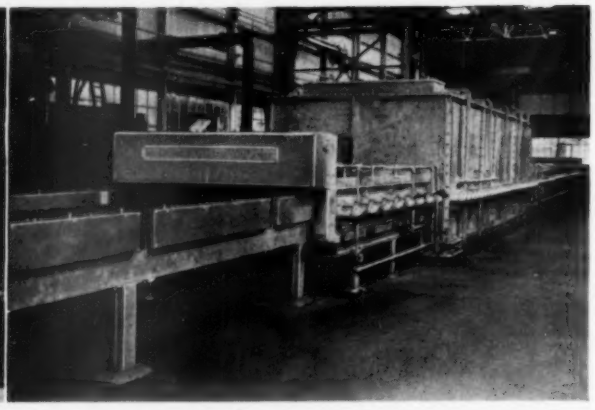
METALECTRIC FURNACES LTD.

SMETHWICK · ENGLAND

FOR ALL FORMS OF ELECTRIC HEAT TREATMENT EQUIPMENT

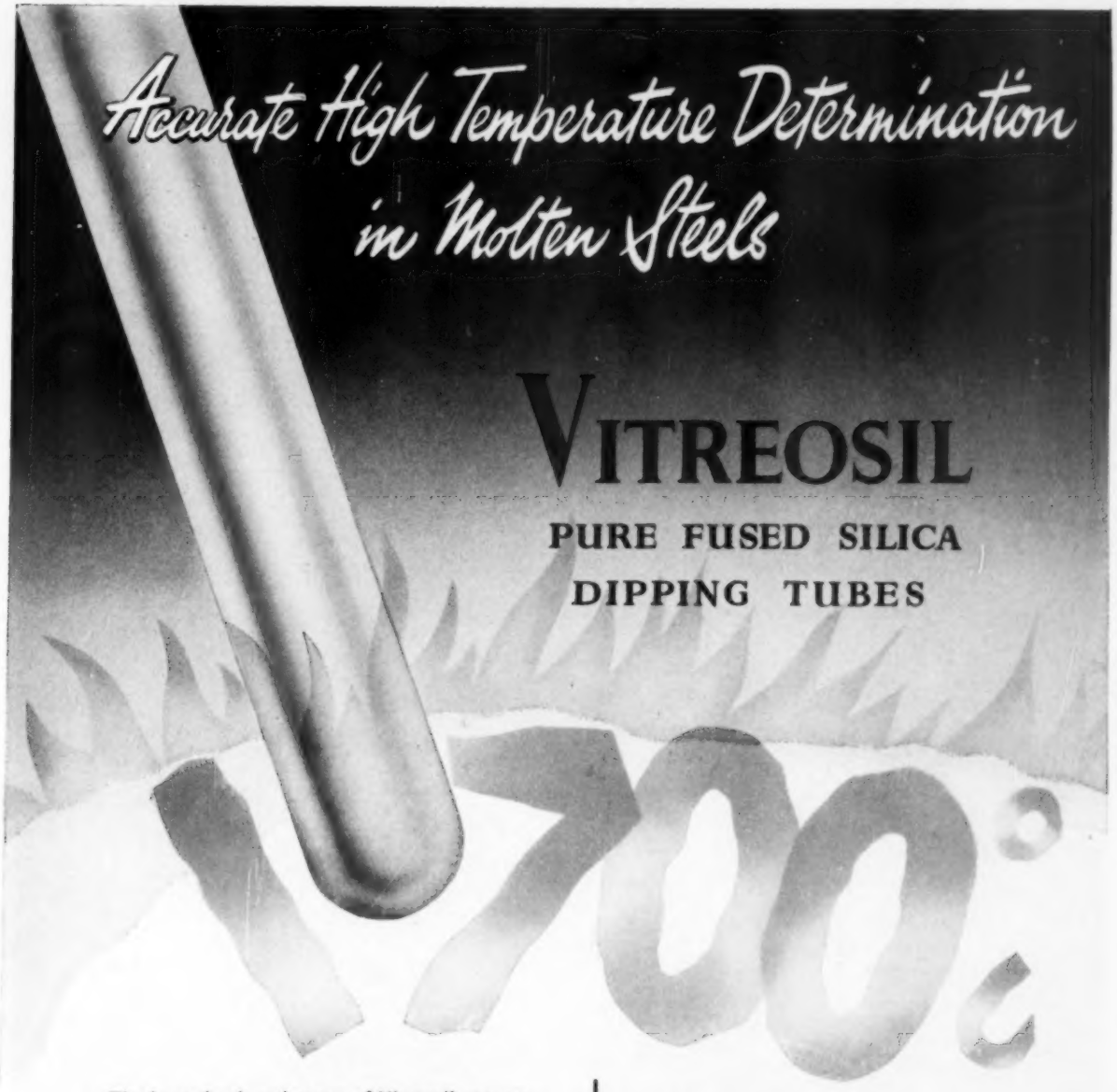


Continuous blackheart and pearlitic malleablizing



Roller hearth bright annealing

13/40D/61



The heat-shock resistance of Vitreosil ensures accurate thermo-couple temperature readings without the slightest risk of contamination in molten steel. The cost of Vitreosil Dipping Tubes, from a few pence each, is negligible in relation to the loss incurred in a sub-standard casting. *Full list of sizes and prices on request.*

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Refractories
THE REFRACTORY BRICK FOR SOAKING PIT
Hearth, lower side walls and Ingot Head Level
STEIN 73
For exceptional durable service
Stein 73 is unrivalled in its resistance to damage
by abrasion and from slag attack.
You are invited to consult our long experience on all refractory problems
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PRIEST

INGOT SOAKING PITS

The illustration below is of a battery of six One-way Oil-Fired Soaking Pits installed at Hallside Works of The Clyde Alloy Steel Company Limited.

Each cell is complete with its own cover operating machine, combustion equipment and automatic controls; one single recuperator and stack serves twin cells.

We specialise in the design and construction of

Open Hearth Furnaces
Soaking Pits of all types
Continuous Multi-zone Bloom and Slab Re-heating Furnaces
Continuous Bogie type Ingot and Slab Heating Furnaces
Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating
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Stress Relieving Furnaces
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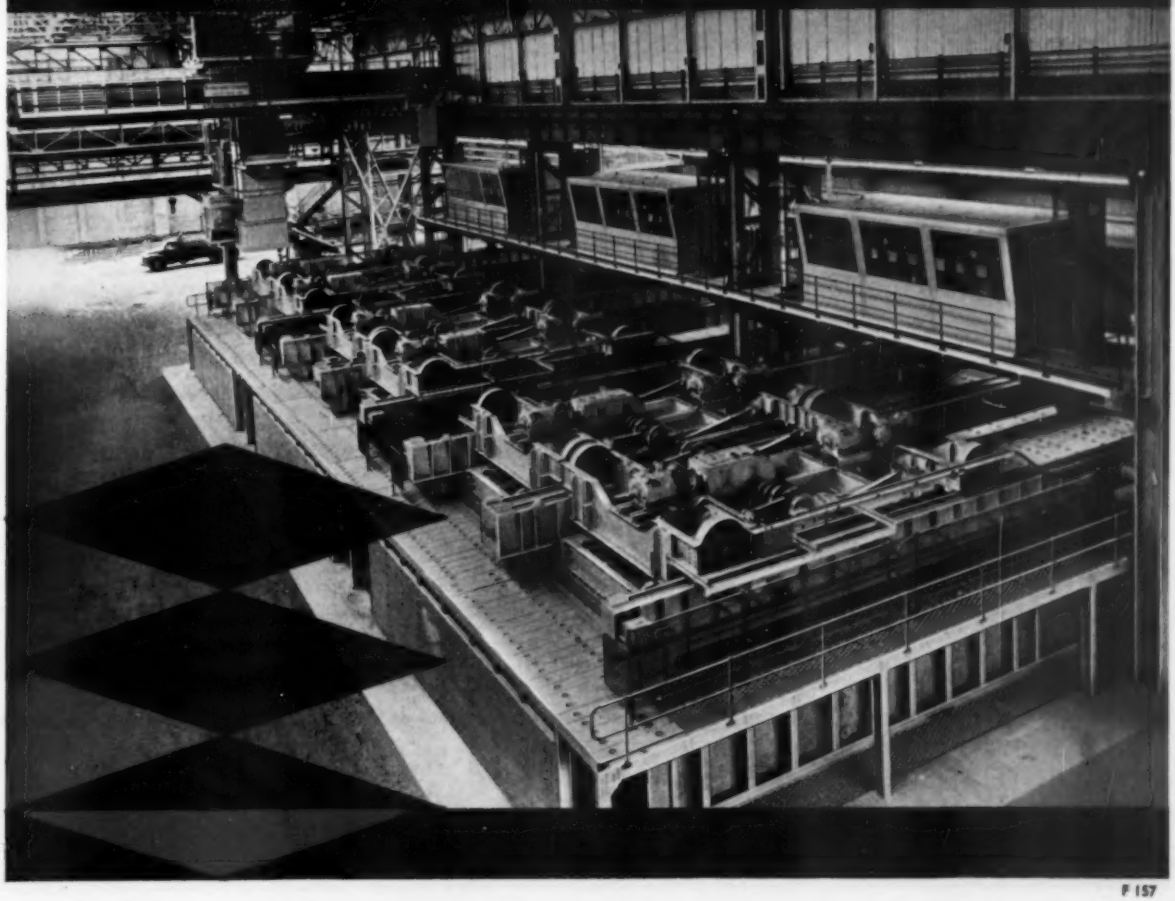

P 157

Can *REFRAX Refractories solve your problems?

REFRAX silicon nitride bonded silicon carbide material is a super refractory made by The Carborundum Company Ltd. It possesses properties which are superior to those of conventional ceramic-bonded refractories and high temperature metal alloys, and which make possible such applications as these:

Extra high temperature applications calling for high stability, strength and thermal conductivity. Burner tips, nozzles and blocks. Kiln furniture. Heating and holding pots for diecast, non-ferrous metals. Support fixtures for heat treatment operations. Immersion thermocouple tubes in corrosive melts. Mixing venturis. Nuts, bolts, tubes, and other threaded assemblies. Cyclone-type classifier parts exposed to abrasive materials suspended in liquid and gas carriers. "Sinker" assemblies in wire aluminising furnaces. Re-ignition devices. Linings for aluminium electrolytic reduction cells. Pumps and pump parts for molten non-ferrous metals. Large number of highly complex shapes available including threaded assemblies and thin section pieces as well as a full range of standard brick.

* REFRAX is a registered trade mark of THE CARBORUNDUM COMPANY LIMITED

- Will withstand temperatures above 1800°C.
- Very high hot strength combined with great resistance to thermal shock.
- Exceptional resistance to abrasion and chemical attack
- Freedom from warping, even under severe conditions.
- High thermal conductivity.
- Adaptability approaching that of metal for intricate designs and thin sections.
- Unprecedented dimensional stability.

Our technical and advisory service is always available to discuss your problems with you. Why not get in touch with us?

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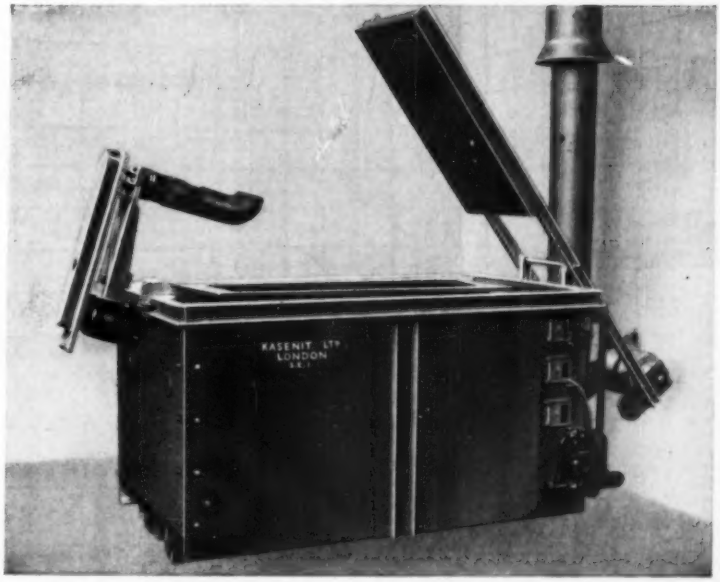

NATURAL DRAUGHT GAS FIRED MAR TEMPERING SALT BATH WITH AGITATOR

Size of bath 36" long × 24" wide × 18" deep

We manufacture all types of Cyanide, and Oven Furnaces suitable for the Heat Treatment of Metals

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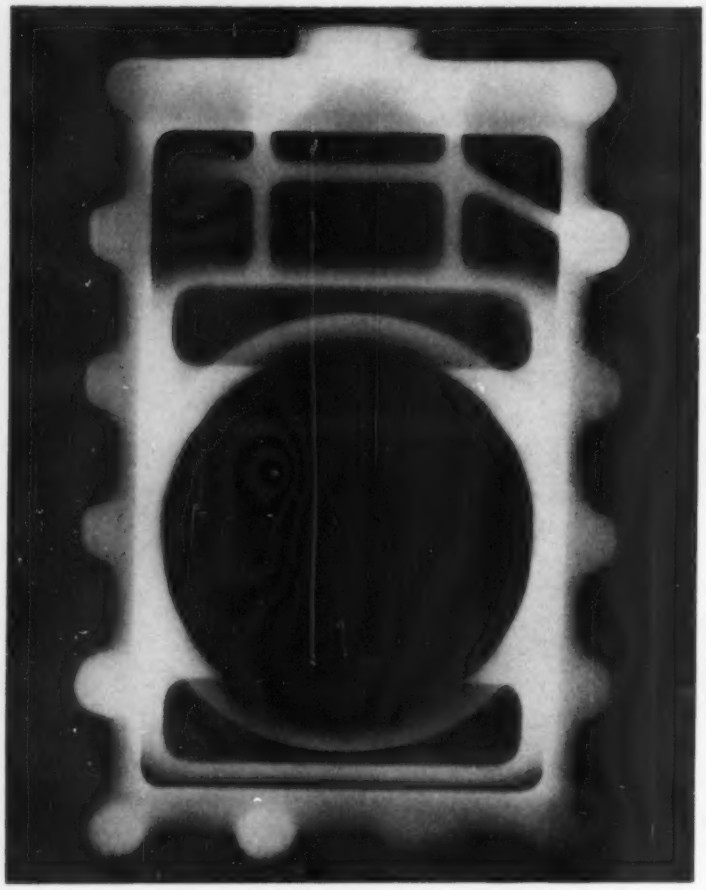

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Engineering, Marine, Welding and Nuclear Energy Exhibition

20th April — 4th May

Empire Hall, Olympia

Where sections vary greatly . . .

. . . 2 films are better than 1

ILFORD technicians pioneered multiple film technique in industrial radiography. This has been graphically described as a "sandwich" of two or more films, and the technique gives vastly superior results where specimens with widely varying densities have to be critically examined.

The "sandwich" consists of two or more films of different speeds loaded into a standard cassette for simultaneous exposure. Thick sections of the specimen register clearly on the faster film, and the thinner sections on the slower film. The effects of differential exposure can be accentuated by using lead screens in the "sandwich". The technique can also be used for making duplicate radiographs by using two films of the same speed.

Choice of the appropriate ILFORD Industrial X-ray films obviously depends on the subject, the tube voltage and the presence or absence of screens. Full details of film choice and voltages, as well as lead screens, will be forwarded by request.

For improved radiographic examination

ILFORD INDUSTRIAL X-RAY FILMS, CHEMICALS, CASSETTES AND LEAD SCREENS

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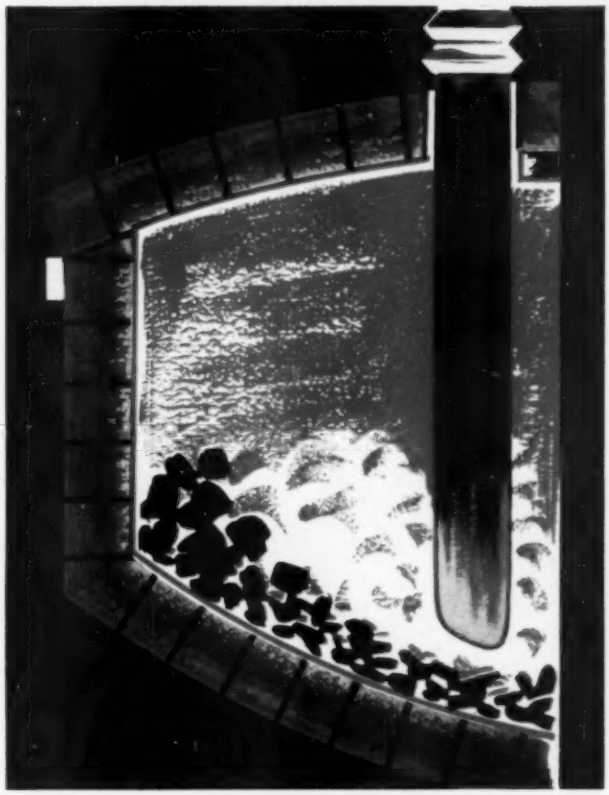

why ACHESON TRADE MARK graphite electrodes

Give You Dependable Service!

"Acheson" Graphite Electrodes are manufactured from specially selected high grade raw materials which are carefully processed at all stages of manufacture under controlled conditions to give a final electrode for your arc furnaces with these properties at their optimum—

LOW RESISTANCE

HIGH MECHANICAL STRENGTH AT OPERATING TEMPERATURES

EXCEPTIONAL THERMAL SHOCK RESISTANCE

"Acheson" Graphite Electrodes are made in the United Kingdom only by

BRITISH ACHESON ELECTRODES LIMITED of SHEFFIELD.

ACHESON

TRADE MARK

GRAPHITE ELECTRODES

The term ACHESON is a registered trade mark

An OASIS in a Rolling Mill....

A continuous procession of white hot ingots a few feet below one's seat all day is enough to make even the most patient operative get 'heated'. But not this gentleman. His employers, Colvilles Ltd., Glasgow, had the foresight to insulate his control cabin with STILLITE mineral wool and to provide a cool filtered air supply. His cabin is the coolest, most pleasant spot in the mill. This picture was taken five years ago, since when several more* have been ordered by Colvilles. For this particular purpose Stillite mineral wool slabs are employed but the Stillite range provides you with mineral wool insulants in a range of densities and forms to meet every purpose.

**Work by Solano Air & Heat Systems Ltd., of Glasgow (Main Contractors), collaborating with Newalls Insulation Co. Ltd.*

STILLITE

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Just attach to letterhead METALLURGIA

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METAL CASED BASIC BRICKS

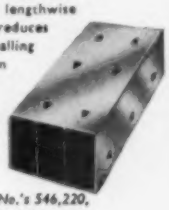
now made by

Pickford Holland

Under sub-licence from General Refractories Ltd., covered by British Patent No. 546,220 for the basic process of metal-cased brick manufacture and other British Patent No.'s 600,630—749,491—778,047 and 778,048.

METALCLAD "EE" BRICKS

Divided internally by two plates placed lengthwise This system reduces flaking and spalling to a minimum and can be applied to all Metalclad shapes and sizes.

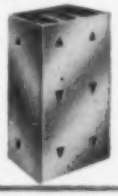


Covered by British Patent No.'s 546,220, 778,047 and 778,048

TABHANGER SUSPENSION

Bricks supplied with a special stainless steel tab co-moulded with the brick embedded into the surface of the top face. By the use of a special tool the tab may be bent out at right angles to the top face to form a hanger.

Covered by British Patent No.'s 546,220 and 749,491



FERROCLIP SUSPENSION

This method allows the brick to be suspended from the end. The Ferroclip hanger slot may be moulded into any roof or wall shape.

Covered by British Patent No.'s 546,220 and 600,630

Make your needs known to Pickford Holland now!

P.H. METALCLAD

Metal cased basic bricks

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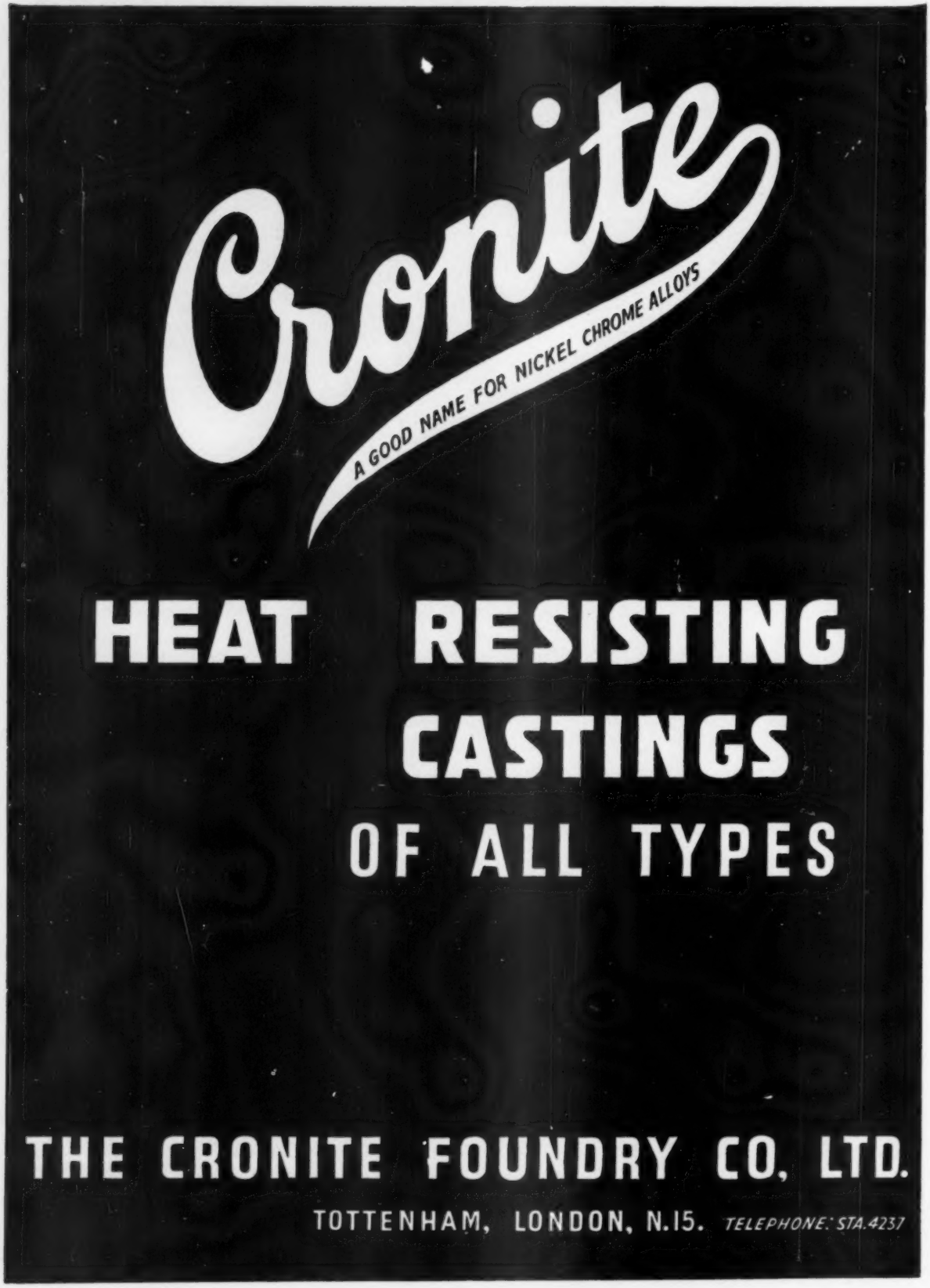
OA/6724


Cronite
A GOOD NAME FOR NICKEL CHROME ALLOYS
HEAT RESISTING
CASTINGS
OF ALL TYPES
THE CRONITE FOUNDRY CO. LTD.
TOTTENHAM, LONDON, N.15. TELEPHONE: STA.4237

EXPERIENCE COUNTS- BUT WHOSE?

There is only one person properly able to judge the merits of one electrode against another—the user. If, then, you know of someone who has bought and tried AGL graphite electrodes, ask him.

He will tell you that their performance is excellent; that their taper-threading gives stronger joints; that they cut down repair time—drastically; and that they are backed by a service as quick as it is reliable.

And if he doesn't tell you this? Then you don't buy AGL electrodes. That's all.

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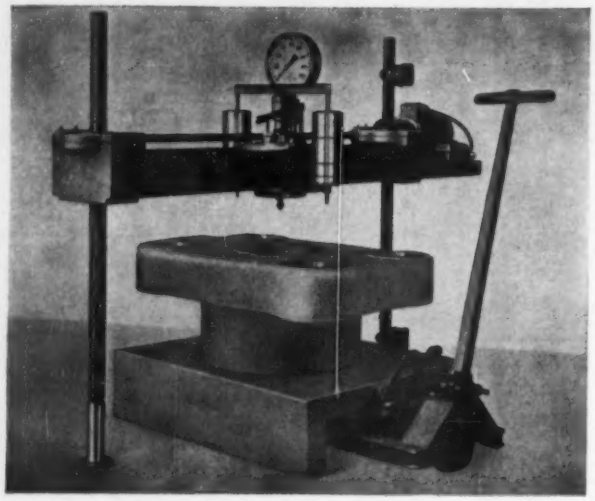
JACKMAN FOR HARDNESS TESTING EQUIPMENT



BRINELL TEST MACHINES

WE SHOW A BEAM TYPE BRINELL MACHINE MOTORISED FOR VERTICAL MOVEMENT.

TEST HEAD CAN BE SLID ALONG BEAM BY HAND.

WIDTH BETWEEN COLUMNS 52"
HEIGHT UNDER TEST BALL 6" TO 60"

STANDARD BENCH TYPE AND OTHER SPECIAL MACHINES AVAILABLE.

PLEASE WRITE FOR BULLETIN No. 2

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FOR RAPID AND ACCURATE DETERMINATION OF CARBON IN STEEL BATHS.

TOTAL TIME OF MAKING TEST 1½-2½ MINUTES INCLUDING PREPARATION OF SPECIMEN. ACCURACY IS ±0·01%C

SIMPLE TO OPERATE.

PROVIDES COMPLETE CONTROL OF STEEL BATH.

USED IN THE LEADING STEEL WORKS OF THE WORLD.

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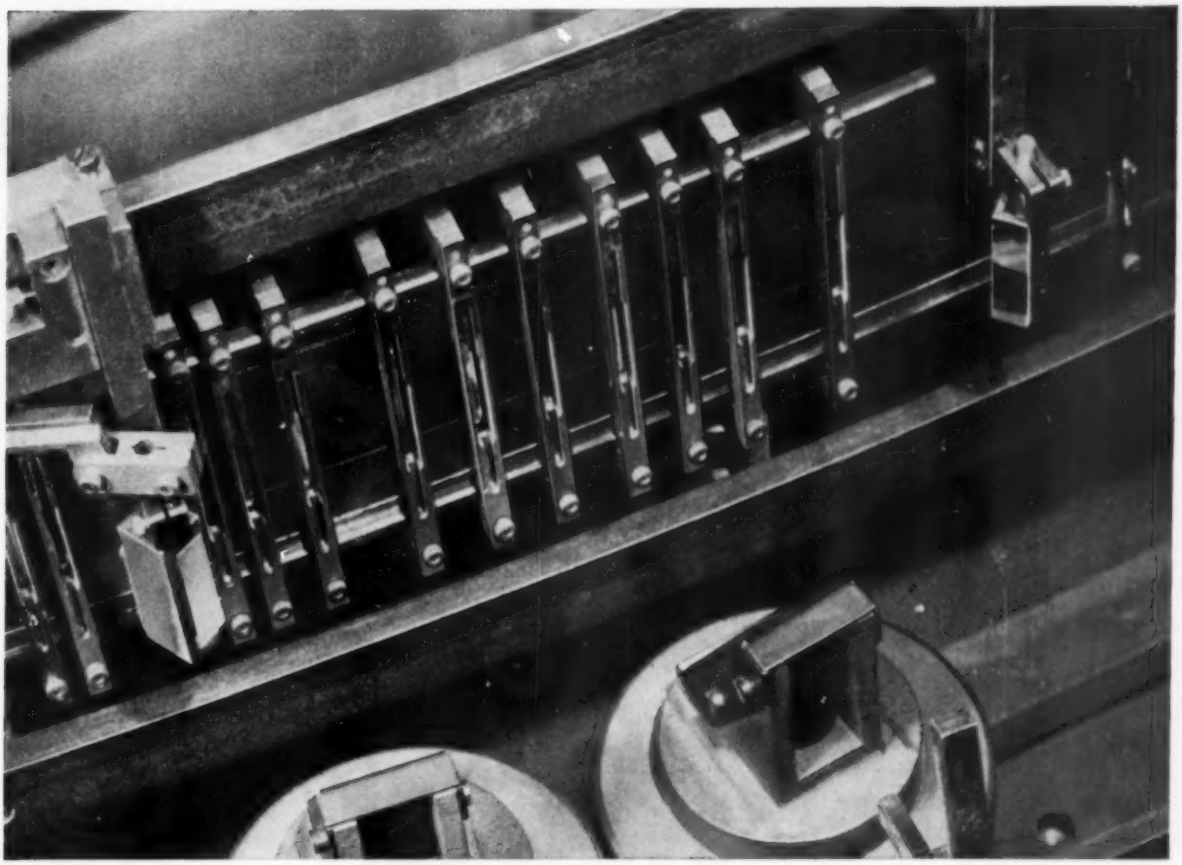
Telephone: DEAnsgate 4648 (3 lines) *Telegrams: BLAST, MANCHESTER*



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Some parts of an automatic spectrograph may look complicated, but no instrument could be simpler to use and maintain, and none could analyse an alloy more quickly or more accurately. Is the specification of your alloys important? Check it with an automatic spectrograph and there will be no doubt about it.

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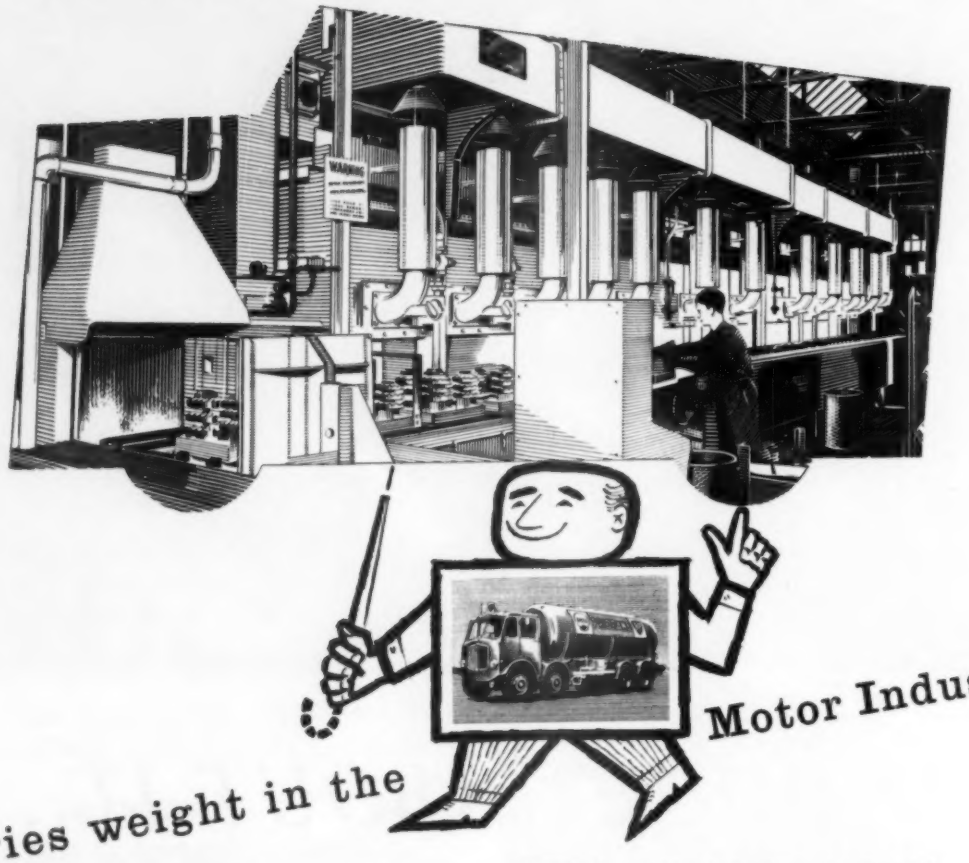
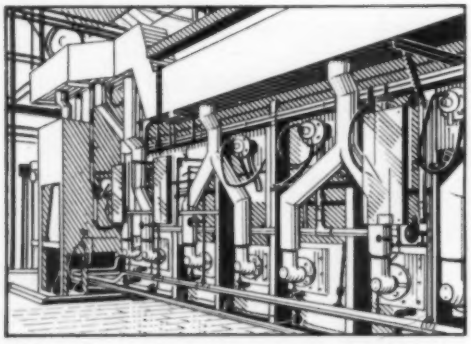
PROPAGAS PROPANE



carries weight in the Motor Industry



These illustrations, by courtesy of Ford Motor Co. Ltd, show two of many continuous gas carburizing furnaces installed at their Dagenham factory, using endothermic atmospheres produced from PROPAGAS.

PROPAGAS provides industry not only with a high calorific value fuel gas (approximately 2,500 b.t.u. cubic foot) but also with an excellent medium for the production of special furnace atmospheres. It is widely used for gas carburizing, carbonitriding and bright annealing of ferrous and non-ferrous metals.

BOTTOGAS Butane, like Propagas, is a petroleum gas delivered and stored as a liquid under moderate pressure. Bottogas is used as a fuel for fork lift trucks and for many other specialised applications.

PROPAGAS Propane and **BOTTOGAS Butane** come from the great British refineries of the Shell and BP Groups, backed by a technical service second to none and with a complete sales organisation covering the United Kingdom.

SHELL Gases BP

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For the right proportions....

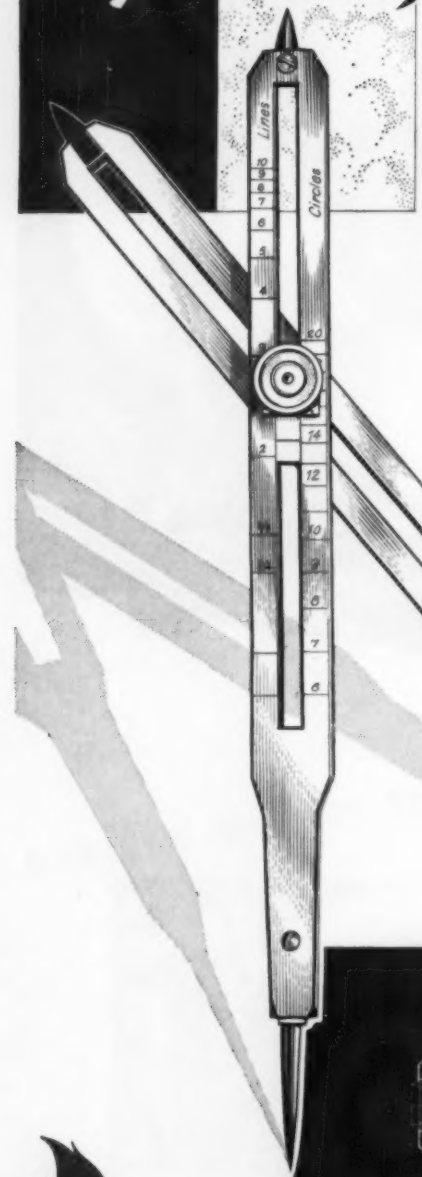
Schieldrop

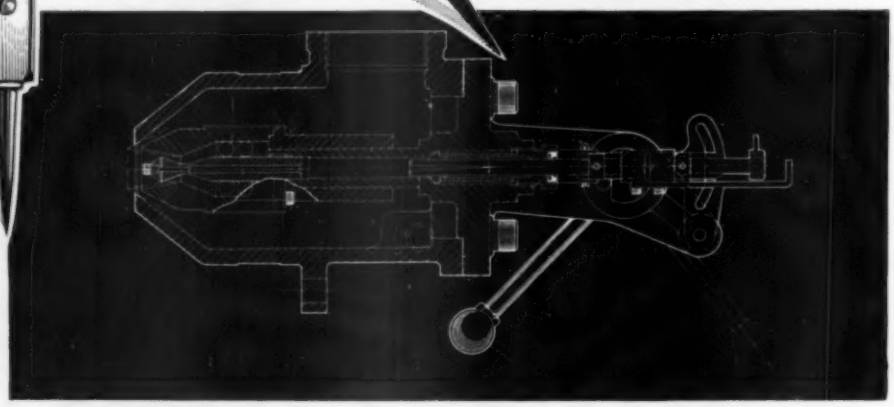
SELF-PROPORTIONING OIL BURNERS FOR CONSTANT AIR-OIL RATIO

Pioneered by Schieldrop in Great Britain, self-proportioning oil burners offer outstanding advantages including peak efficiency and real economy of operation. Write for full details of Schieldrop burners.

Note these features—

1. Single lever control.
2. Easy adjustment for high and low flame settings.
3. Simple and robust construction.
4. Constant velocities of both primary and secondary atomising air, giving uniform flame over a 5-1 turn-down range.

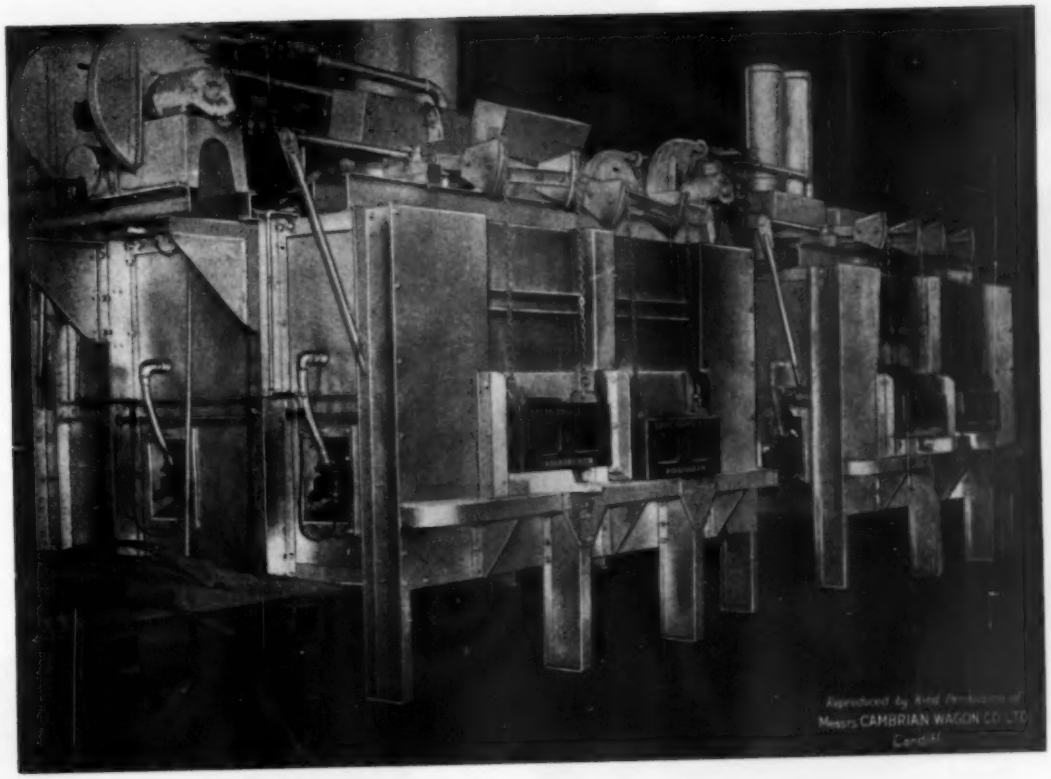




Schieldrop & COMPANY LIMITED

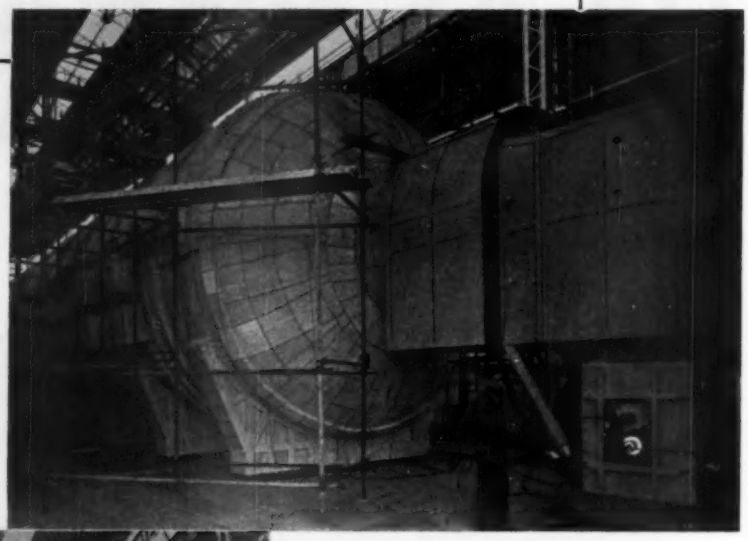
STOTFOLD, BEDS. Phone 414 (4 lines)

LUCAS FURNACES LTD
BIRMINGHAM

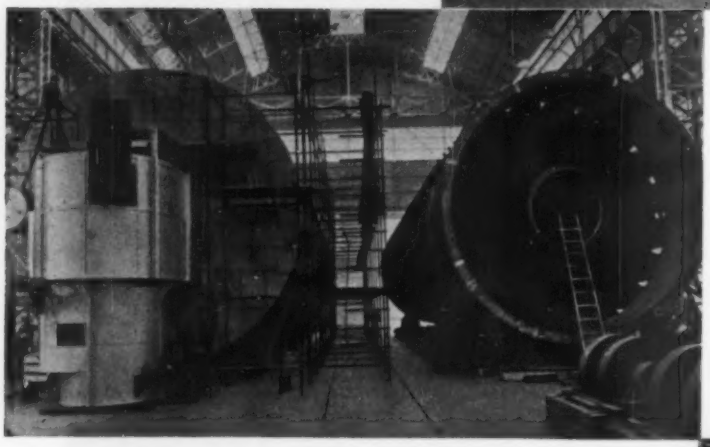


COMPLETE INSTALLATIONS AND FURNACE CONVERSIONS

SITE STRESS RELIEVING



Oil fired convection heating for stress relieving at Nuovo Pignone Company, Massa Carrara, Italy. Heat Exchanger vessels for the Atomic Power Station of Eni-Agip at Borgo Sabotino.



Equipment supplied by Felind Forni Industriali S.R.L Milan (Dowson & Mason's Italian associates)

Technical Details

Outside diameter	5.7 metres = 18′ 9″
Overall length	24 „ = 79′ 0″
Weight	220 tons

Total fuel oil consumption	5000 Kilos = 1250 gallons
Oil used per ton	= 2.27 Kilos = 5.68 gallons
Heating and soaking time	49 hours
Temperature uniformity	20°C between 500 and 620°C.
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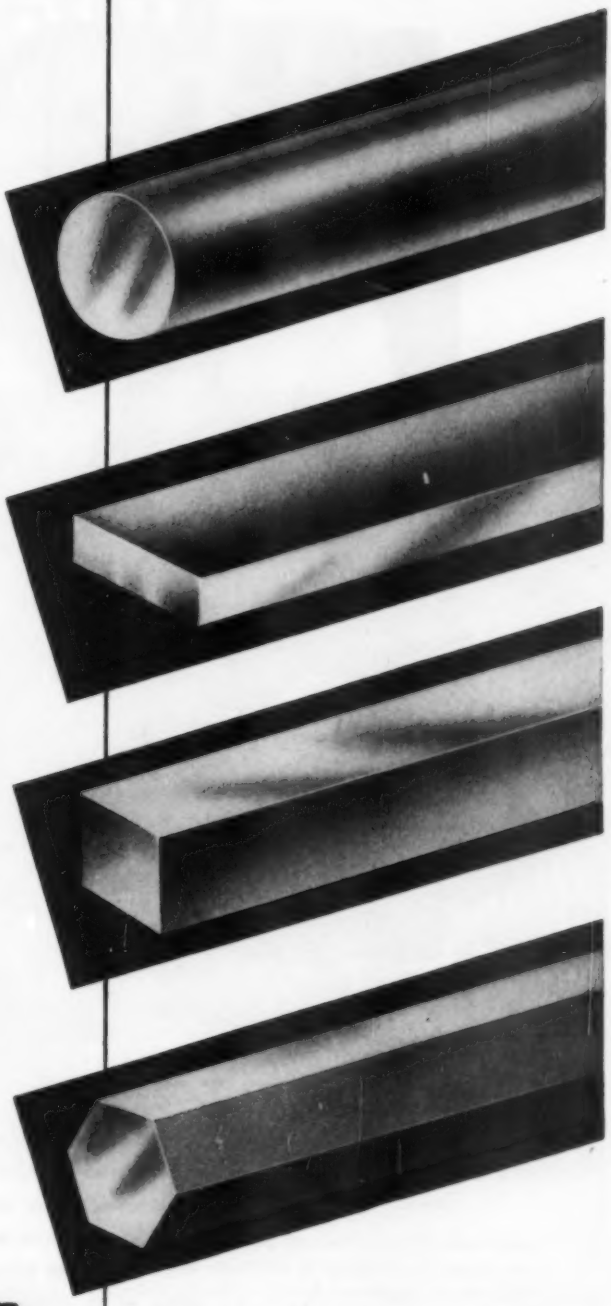

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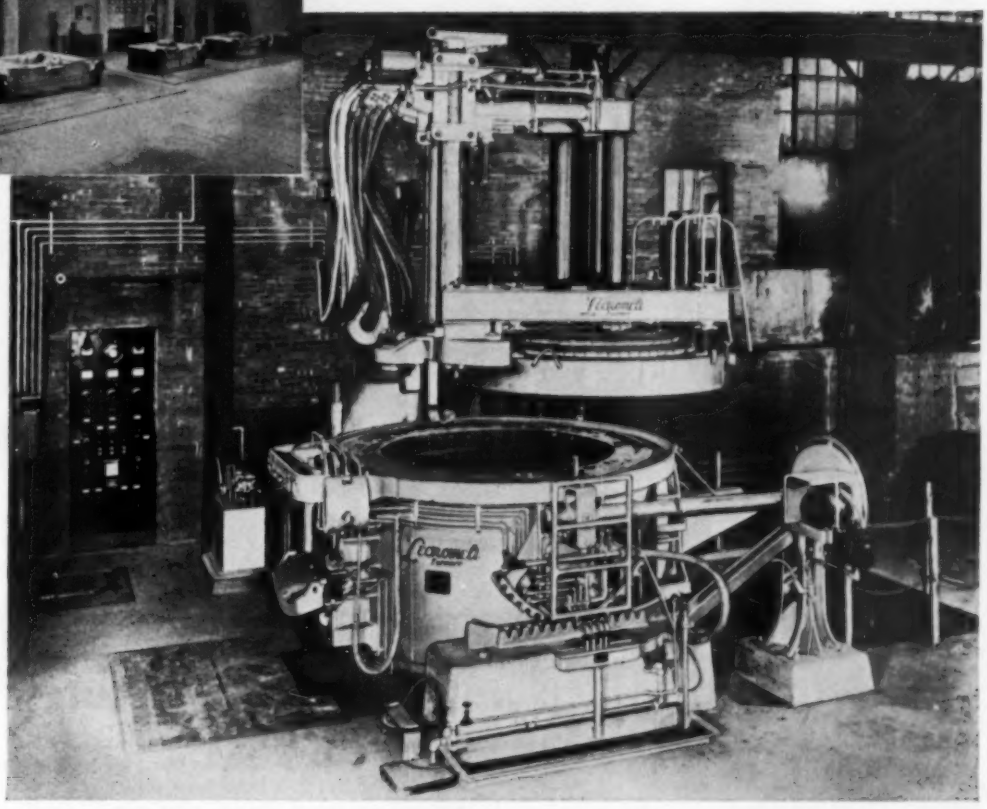

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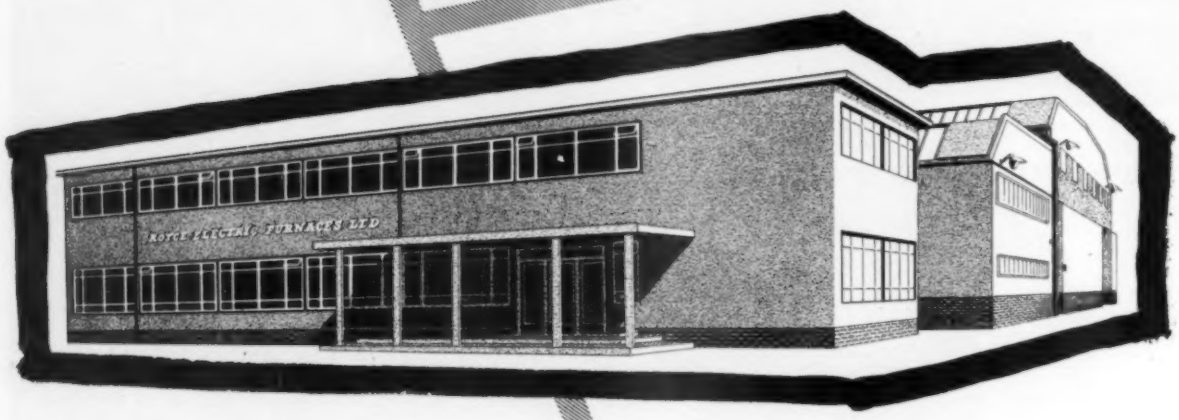

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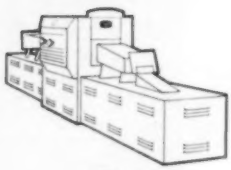

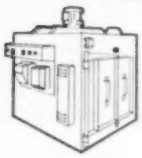

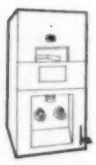

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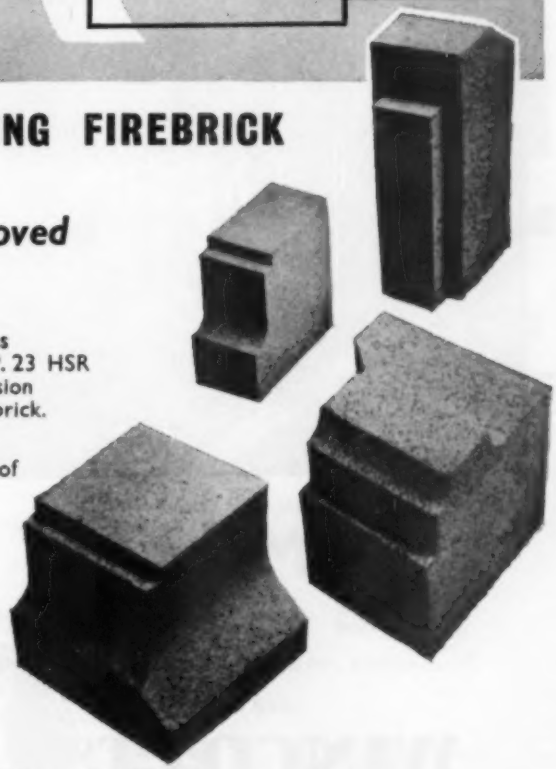

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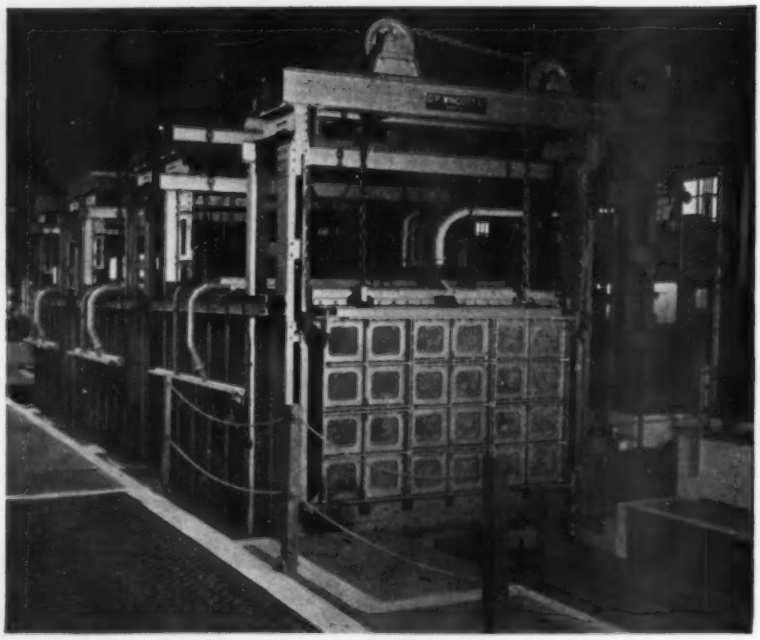

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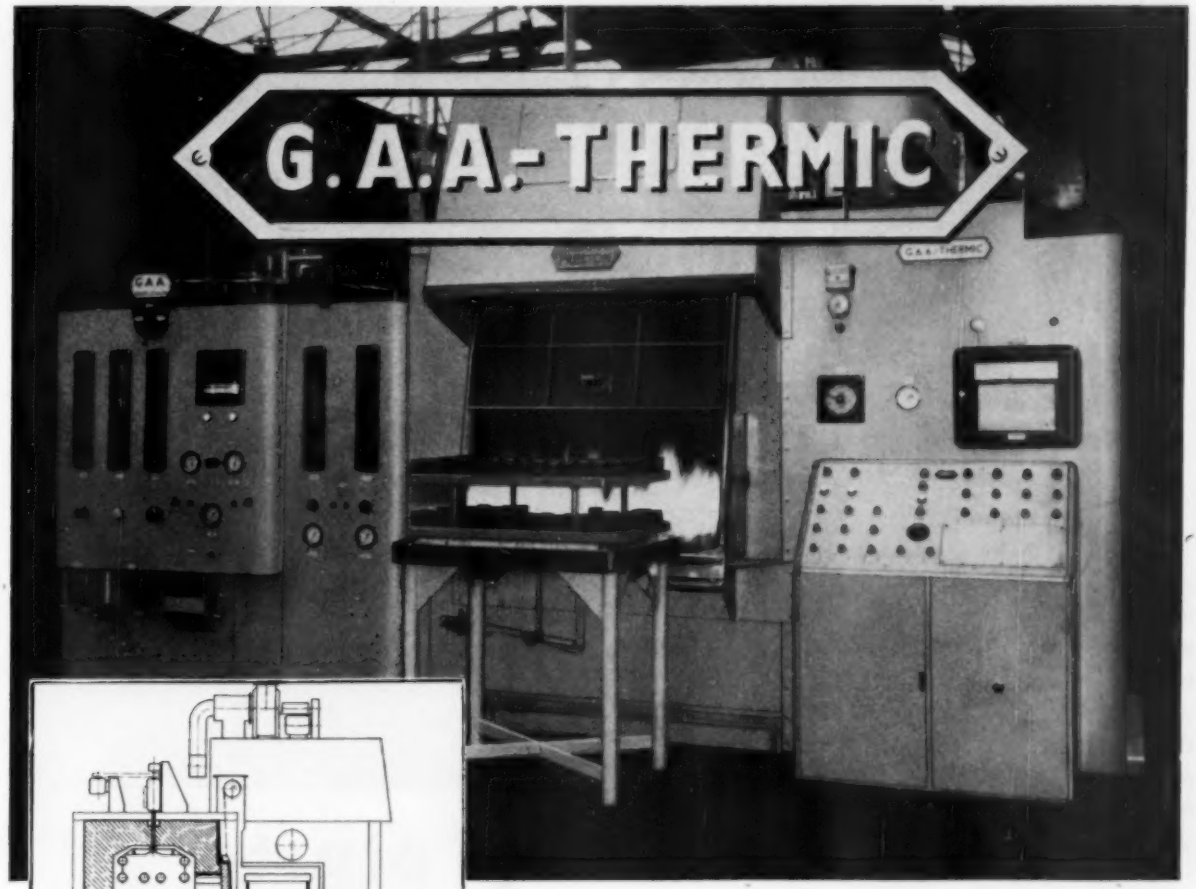

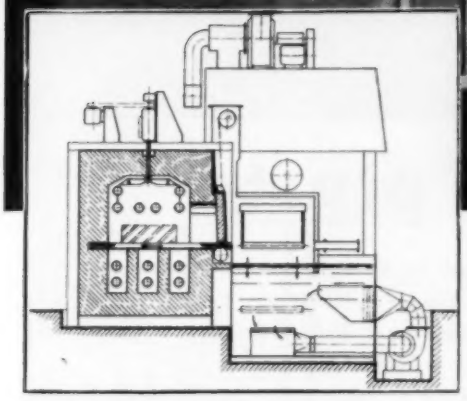

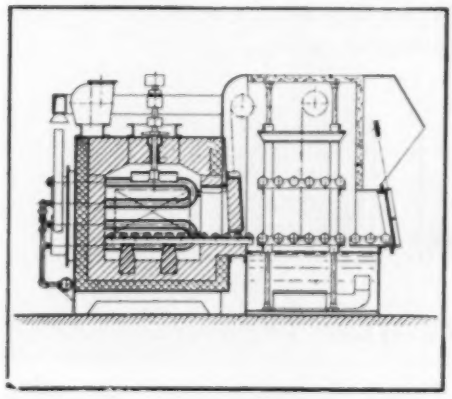

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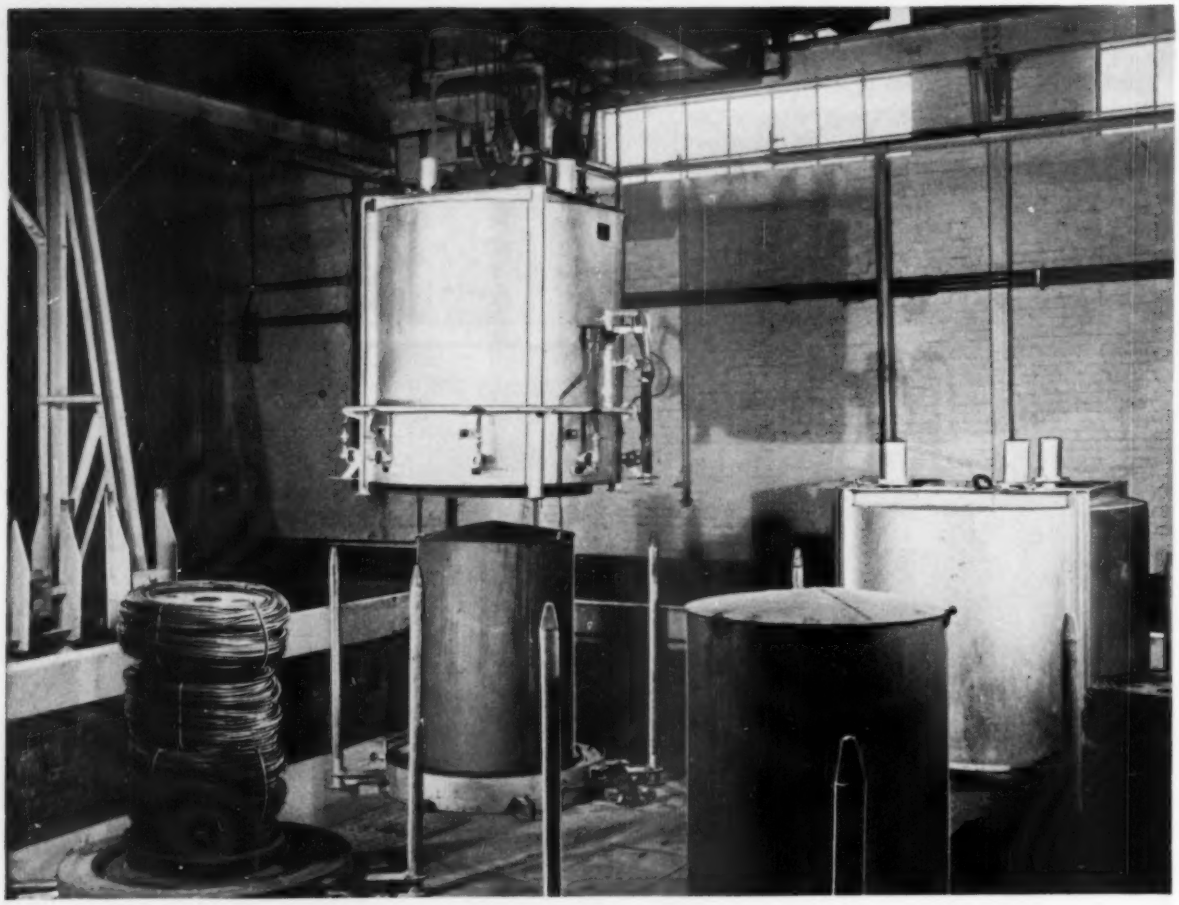

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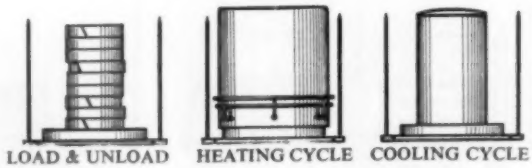

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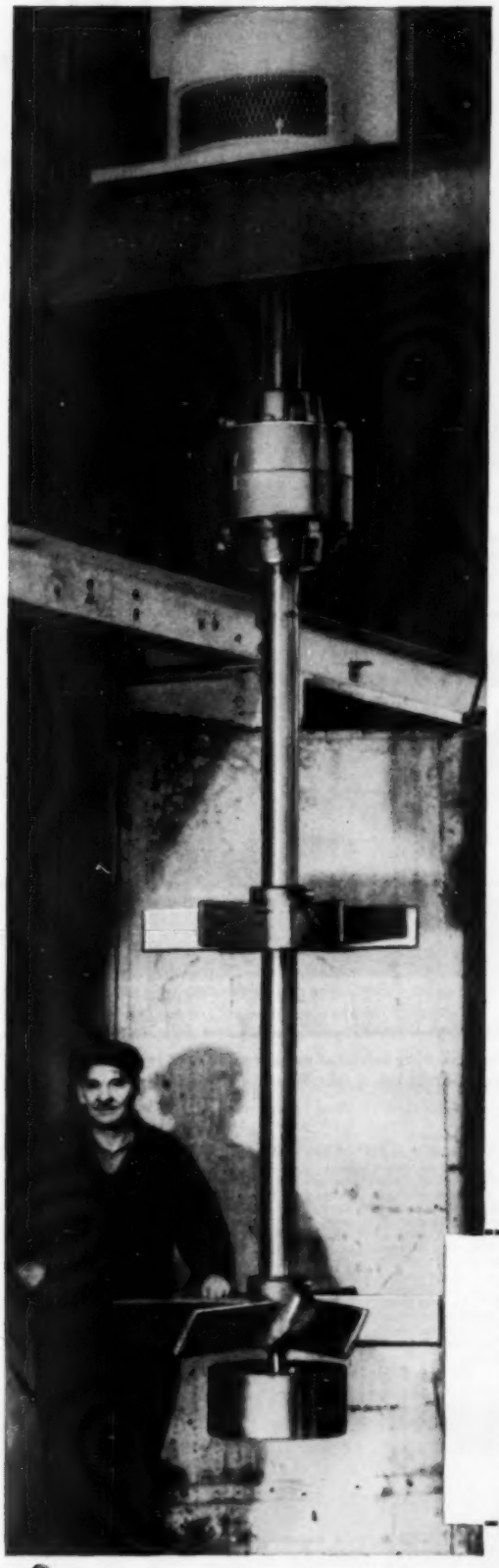

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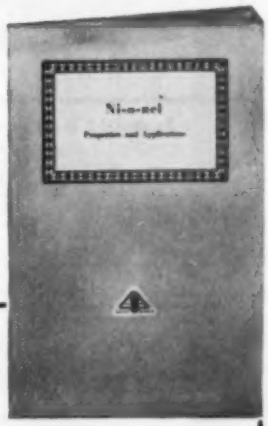

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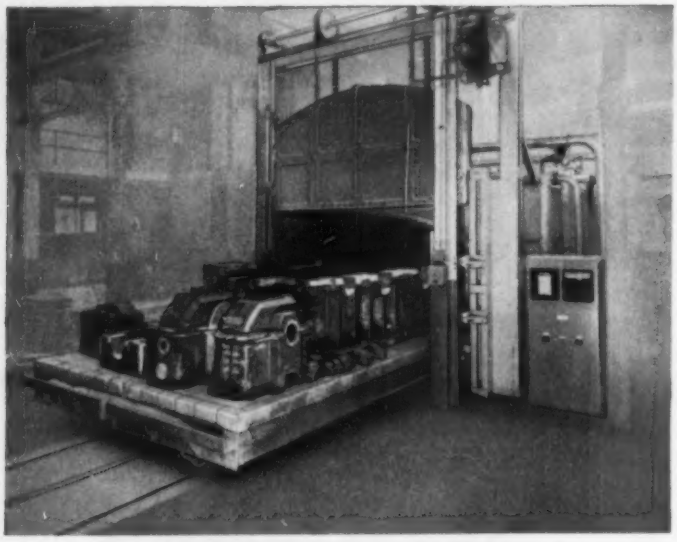

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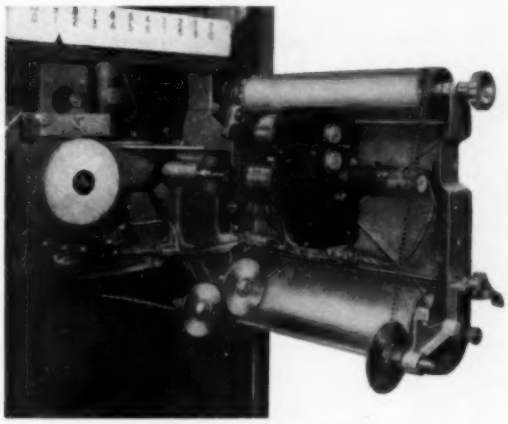

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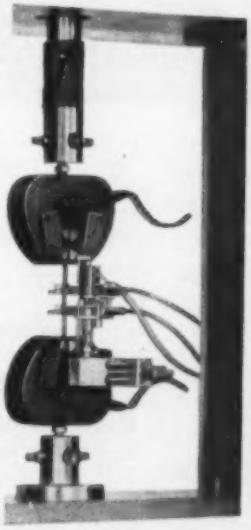

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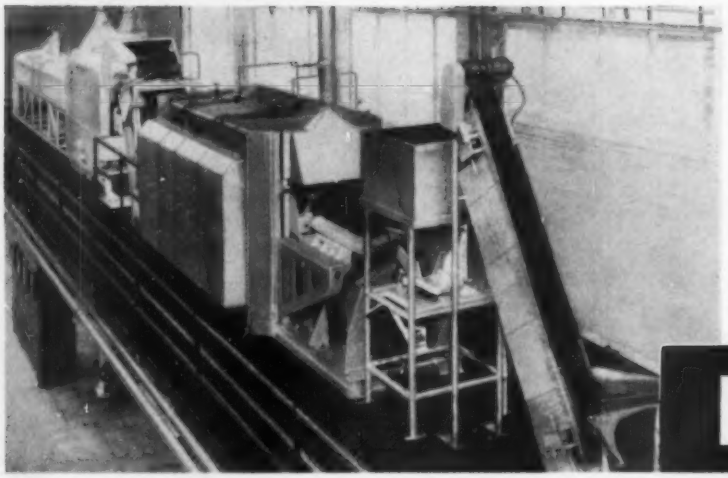

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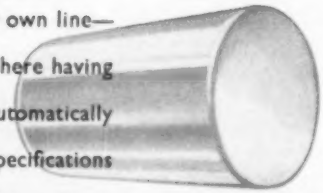

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CONTENTS FOR APRIL, 1961 Vol. 63 No. 378.

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.
31, King Street West,
Manchester, 3.
Telephone : BLAckfriars 2084

London Office :

158, Temple Chambers,
Temple Avenue, E.C.4.
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APRIL, 1961 Vol. LXIII. No. 378

Much Ado About Nothing

THE theme of a symposium held in London in the early days of last month was, "User Experience of Large Scale Industrial Vacuum Plant." The need for vacuum arises in a number of industries, including those dealing with chemicals, metals, food, pharmaceuticals, nuclear energy, oil, and veterinary products, to name but a few, and most of these aspects found a place in the discussions of those attending—some three to four hundred in all. The symposium was sponsored by The Joint British Committee on Vacuum Science and Technology, and arranged by The Institution of Mechanical Engineers, on whose premises it was held, a fact which prompted one speaker to remark that as a veterinary surgeon it was with some trepidation that he rose to speak in the stable of the "iron-horse."

In his introductory address, Mr. N. A. McNeill, Unilever's engineer-in-chief, summarised the most important reasons for the use of sub-atmospheric pressures as follows: (*a*) to permit process operations at a temperature sufficiently low that the material in process is not affected adversely by reason of destruction or by change of its inherent properties; (*b*) to prevent contact with the material by air or other gases which might promote oxidation; (*c*) to permit process procedures to be maintained when otherwise they would be restricted or impossible; (*d*) to obtain from a given source of heat energy a larger overall temperature differential than would otherwise be possible; (*e*) to obtain a greater throughput in processes and to enable the process to be progressed to a greater extent; and (*f*) to obtain greater sterility and longer keeping properties for pharmaceuticals and certain food products.

The equipment for producing the required vacuum varies considerably in form and design, according to the degree of vacuum required, ranging as it does from little below atmospheric pressure, down to absolute pressures as low as a fraction of a micron. In all vacuum operations the evolved gases must be compressed from the low operating pressure to above atmospheric pressure, and mechanical compressors or vacuum pumps find their widest application for pressures between 5 mm. Hg and atmospheric. They are used extensively as backing pumps for devices producing lower absolute pressures, such as molecular pumps, diffusion pumps, or vacuum augmentors. For installations of moderate size there are mechanical vacuum pumps of the oil-sealed type which can be used for absolute pressures of 1 micron or less, although at very low pressures the volumetric efficiency is reduced substantially. As an alternative to the mechanical vacuum pump, wide use is made in industry of ejectors of single- or multi-stage type for compression from as low a pressure as 200 micron, or as backing units. The choice of pumping equipment depends on a number of factors, such as: the compression ratio and the density of the gas being compressed; the nature and amount of the gas involved; the value of the gas and the need to recover it; and the economics of the operation.

Vacuum metallurgy has made great strides since the war, and has made possible the production, in commercially attractive form, of several metals and alloys which would otherwise have remained laboratory curiosities. This is particularly true of the reactive metals, such as titanium and zirconium, whose production in massive workable form has been based on the consumable electrode vacuum arc furnace, in which an arc is struck between an electrode of the material to be melted (made by welding together compressed "powder" compacts) and a base charge in the bottom of a water-cooled copper crucible. The metals division of Imperial Chemical Industries, Ltd., has had considerable experience with this process and the details of the equipment used were given in one of the papers. The authors discussed the successively larger furnaces (up to 2 tons of titanium) that had been built, and suggested that the way is clear for the introduction of even larger equipment, operating at lower pressures, manned by suitably trained production workers. This matter of training is one of some importance as in the words of the authors: "Experience has shown that everyone associated with the use of vacuum equipment must be suitably trained and ready to adapt himself to the disciplines demanded by the new technique. These disciplines have set valuable standards, new to established metal-producing plants."

Because the capital cost of vacuum equipment is high, and increases sharply with reduction in operating pressure, it is essential that the vacuum requirements of the process should be assessed carefully, and for each installation the closest co-operation between the user and the maker of the vacuum equipment is essential.

Besides the production of reactive metals, the vacuum arc process is used for melting steels where exceptionally clean material is required, such as for the manufacture of heavy duty bearings, aero engine discs, and hard rolls for foil rolling. Vacuum melting is only called for where the cost is justified, and it seems likely that before vacuum equipment finds wider application for the processing of lower priced materials, it may have to undergo certain changes, such as simplification of the pumping system and pump design, so cheapening automatic control and facilitating its wider application. To obtain the best use of equipment, greater use will have to be made of devices designed to increase plant utilisation.

The other technique of vacuum melting which has made considerable progress in recent years makes use of an induction furnace as the melting unit. Whilst vacuum equipment for such plant has improved greatly, there are still a number of aspects which are not satisfactory. Faults which may give rise to trouble, according to the authors of another paper, are: loss of oil from the booster or diffuser pump due to a valve failure; and carry-over of metal particles into the rotary pump

causing eventual seizure of the moving parts. If to the high capital outlay and relatively low production rate are added heavy maintenance costs, prospects for vacuum induction melting are not too healthy. In the opinion of workers with experience in this field, however, many of the operational difficulties encountered could be avoided with an improved design. It may be that preliminary outgassing of charges in the charging locks, combined with semi-continuous casting in separate mould chambers will make possible the attainment of melting times comparable with those achieved in conventional air melting practice, when the premium for vacuum-melted material will have to cover only the higher capital depreciation and maintenance.

In the discussion, Mr. G. T. Harris of Jessop-Saville, Ltd., commented on the two processes of vacuum melting, confirming that the vacuum arc process is relatively trouble free, with a rejection figure of less than 1%, and that down-time and maintenance amounts to only 3% of the total cost of plant operation. More practical problems arise in vacuum induction melting, where the complexity of the plant makes it more vulnerable to errors. The figure for down-time and maintenance is, in this case, much higher than 3% of the melting cost. Increase in size of the plant would lead to a reduction in melting cost per ton, and there appears to be no practical objection to going to much larger sizes, at least in vacuum arc plant, and a unit of this type for 40 in. diameter ingots weighing 25-50 tons is being built in the United States. Again, in the production by induction melting of steels for operation at elevated temperatures, it may cost £50 to analyse, creep test and release a cast weighing 100 lb., i.e. 10s./lb., whereas the same tests on a 1 ton cast would work out at only 6d./lb.

Mr. Harris referred to the fact that his company had had to go to Germany and the United States for vacuum melting plant, and he was but one of a number of speakers who complained that British manufacturers are lagging in design and construction in this field. It was evident, from the discussion as a whole, that the " tailor-made " nature of vacuum equipment calls for the fullest co-operation between customer and manufacturer at the outset. As for the particular, so for the general, and the more the potential user knows about the problems of the manufacturer, and the more the manufacturer knows about possible future demands, the more rapid will progress become. In this context, we feel sure that the airing of grievances as well as the sharing of experiences at this symposium cannot but have been to the benefit of the maker and user of " nothing."

Stainless Steel Exhibition

FOR several weeks past there has been staged at the Mayfairia Rooms, Bryanston Street, London, W.1, an exhibition illustrating the place of stainless steel in present day life. Sponsored by the Stainless Steel Manufacturers' Association, the exhibition is open free to the public daily until 4th May, 1961.

Five-fold Expansion

Since the war, production of stainless steel has expanded five-fold—from 44,300 tons in 1945 to 220,000 tons in 1960. This latest figure represents over £50 million worth of finished rolled products, and the industry has many expansion schemes in hand, whereby, it is estimated, annual production will be increased to 280,000 tons by 1963. The largest bulk users of stainless steel today are the manufacturers of domestic appliances of all kinds and the motor car industry, where it is being used in considerable quantities for " trim." There is, however, hardly an industry which does not use stainless steel in one way or another : from London's new office buildings to the latest design in tableware, and from modern industrial equipment to progress in aircraft construction, the various grades of stainless steel are finding a place.

Where high standards of hygiene are essential, as in hospitals, stainless steel is widely used for instruments and appliances, and in the preparation and handling of food, both in catering establishments and in the home, much of the metal equipment is made from stainless steel. On the industrial scale too, it is used in handling such contrasting beverages as beer and milk ; pharmaceutical products and dyestuffs ; and in processing man-made fibres ; to name but a few such uses.

The first commercial use of stainless steel more than forty years ago was in the manufacture of table knives, and today almost every knife produced is stainless. In the production of spoons and forks, too, stainless steels are now being used to an increasing extent—a growth which owes much to the development of multiple polishing machines for this purpose—and more than fifty designs of cutlery are on show in the exhibition. The excellent properties of stainless steel have recently attracted the attention of many young designers throughout Europe, and an increasingly large range of elegantly designed tableware is, in consequence, now becoming available.

Architectural Uses

Architecture is another field where stainless steel is coming into its own. Used in curtain wall construction it provides an attractive corrosion resistant exterior for buildings : the first to feature it in London will be the Vickers building on Millbank. Stainless steel is already extensively used for shopfronts and interiors, and ample proof of its corrosion-resisting properties is provided by the bright appearance of the facia on the front of the Savoy Hotel, which was erected over thirty years ago.

The strength of stainless steel at elevated temperatures has long been recognised for turbine blading, and since the war for the many highly stressed parts of aircraft jet engines. Moreover, the supersonic aircraft of the future may be built entirely of stainless steel because of the high skin temperatures likely to be experienced.

Exhibitions such as the present one should do much to create a greater awareness in the general public of the potentialities of stainless steel and, in consequence, should increase the already substantial demand. Continued expansion and extension of specialised steel melting and rolling equipment aims at meeting this increased demand, and alongside this expansion, research on the development of new steels is helping to cope with the problems of the future.

The Effect of Thermal Treatment on the Constitution of 80-20 Nickel-Chromium Alloys Hardened With Titanium and Aluminium

By E. A. Fell, B.Met., A.I.M.*

The nature and morphology of the phases present in 80-20 nickel-chromium-base alloys hardened with titanium and aluminium have been investigated by X-ray diffraction and optical and electron microscope techniques. The precipitation reactions have been studied with particular reference to heat treatment schedules, the effect of variations in titanium, aluminium and carbon contents and the influence of internal stress. The precipitates identified were titanium carbonitride—Ti(C, N)—the chromium carbides Cr_7C_3 and $Cr_{23}C_6$, and two Ni_3Al-type phases. High titanium and aluminium or low carbon contents increase the normal rate of the carbide reaction $Cr_7C_3 \rightarrow Cr_{23}C_6$. During ageing in the temperature range 500°–800° C. internal stresses promote precipitation of $Cr_{23}C_6$ along slip planes and in cellular form at the grain boundaries. The possible effect of constitution and the coherence and morphology of the phases present on mechanical properties is discussed.

THE development from the oxidation-resistant 80-20 nickel-chromium-base alloys, of Nimonic 80† and similar age-hardenable, creep-resistant alloys has been described by Pfeil, Allen and Conway.[1] Subsequently, improvements in production techniques made possible increases in the titanium and aluminium contents of the alloys and, together with the addition of cobalt and molybdenum, led to the development of the alloys Nimonic 80A, 90, 95, 100 and 105. Some details of this work, and a comprehensive survey of the alloys, have been given by Betteridge.[2]

The structural work of Taylor and Floyd[3,4] on the system Ni-Ti-Al has defined the conditions for the existence of phases of the types $Ni_3Al(\gamma')$ and $Ni_3Ti(\eta)$. The basic hardening mechanism for the type of alloy discussed in the present paper arises from the precipitation of the Ni_3Al-type phase. It has, however, been shown by Betteridge and Franklin[5] that the precipitation of chromium-rich carbides determines the amount of creep extension which occurs before fracture, and since a critical balance between creep-resistance and ductility is essential in a successful alloy, precipitation of carbides must have a significant bearing on the stress-rupture properties of this type of alloy.

The occurrence and distribution of the precipitated phases present in age-hardening 80-20 nickel-chromium-base alloys has now been studied in detail, as part of a general programme of research on the constitution and morphology of phases present in nickel-base alloys for high-temperature applications. The techniques mainly used were X-ray diffraction of residues from electrolytic separations and of solid samples, electron microscopy and diffraction of extraction replicas, and optical microscopy of solid samples.

The effects of variations of both time and temperature of heat treatment on constitution and morphology in a typical alloy are first considered, and this is followed by a discussion of the modification of structure produced by variations in content of those elements known to be of importance. Subsequently, some of the effects of strain on the kinetics of precipitation are indicated from the examination of quenched and creep-tested specimens.

* The International Nickel Co. (Mond), Ltd., Development and Research Department, Birmingham.

† Attention is drawn to the fact that Nimonic is a Registered Trade Mark.

TABLE I.—COMPOSITION OF THE ALLOYS (weight %)

Cast No.	C	Fe	Co	Cr	Ti	Al
1	0·05	0·32	1·03	19·8	2·27	1·47
2	0·01	N.D.*	<0·1	20·2	1·56	0·77
3	0·02	"	"	19·6	2·60	1·31
4	0·05	"	"	19·7	3·08	1·42
5	0·03	"	"	20·2	1·34	1·28
6	0·01	"	"	19·1	1·84	1·72
7	0·01	"	"	20·0	2·22	2·09
8	0·05	"	"	20·2	0·54	1·57
9	0·03	"	"	20·0	1·34	2·49
10	0·03	"	"	20·0	1·53	2·78
11	0·08	"	"	19·8	1·87	0·56
12	0·07	"	"	19·7	2·63	1·29
13	0·09	"	"	19·1	3·12	1·47
14	0·08	"	"	20·4	1·45	1·28
15	0·08	"	"	20·4	1·87	1·76
16	0·07	"	"	19·9	2·27	2·19
17	0·07	"	"	20·6	1·05	1·71
18	0·07	"	"	20·3	1·35	2·29
19	0·05	"	"	19·9	1·69	2·80
20	0·12	"	"	19·8	1·72	0·83
21	0·14	"	"	19·7	2·65	1·24
22	0·12	"	"	19·4	3·20	1·43
23	0·15	"	"	20·0	1·34	1·22
24	0·13	"	"	19·9	1·97	1·84
25	0·12	"	"	19·6	2·56	2·11
26	0·09	"	"	20·6	0·76	2·20
27	0·09	"	"	20·1	1·14	2·56
28	0·11	"	"	19·8	1·55	2·83

*N.D. = Not Determined.

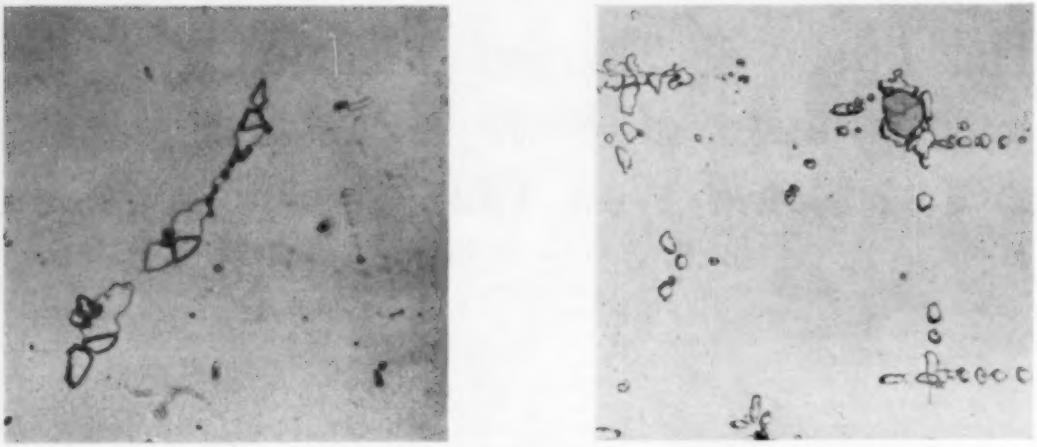
Finally, the effects of heat treatment on the creep and stress-rupture properties of Nimonic 80A, as determined by Betteridge and Franklin,[5] are discussed in relation to observations made during the investigations of structure now reported.

In this work, no attempt was made to achieve the degree of homogeneity usual in constitutional studies, since it was intended that the alloys should approximate as closely as possible to those used in engineering practice. As a result, the various reactions occurring took place over a wider range of temperatures than would have been the case for specially homogenised alloys.

Experimental Procedure

Production of Test Samples

With the exception of Alloy No. 1 (Table I), which was from a typical commercial cast, the alloys were produced by air-melting in a small high-frequency furnace. All the alloys were used in the form of 4 in. long samples of $\frac{5}{8}$ in. diameter hot-worked bar. The analyses are given in Table I.



(a) × 1,000 (b) × 1,000

Fig. 1.—Photomicrographs of samples of a heat of Nimonic 80A alloy heat treated for 2 hours at 1,200° C. + 750 hours at 1,000° C., illustrating the formation of the second Ni_3Al-type phase near (a) $Cr_{23}C_6$ particles at a grain boundary; and (b) Ti(C,N) particles within the grains.

Heat Treatment

During this investigation, the following four heat treatments were applied prior to ageing :—

Treatment A : Heated for 2 hours at 1,200° C. and air-cooled. Most of the minor phases were taken into solution by this heat treatment, but titanium carbonitride remained undissolved.

Treatment B : Heated for 8 hours at 1,080° C. and air-cooled. This is the solution-treatment normally applied to Nimonic 80A prior to ageing.

Treatment C : Heated for 8 hours at 1,080° C., transferred to a furnace standing at 850° C., and held for 24 hours before air-cooling. This treatment is known to improve stress-rupture ductility at some cost in creep-resistance.

Treatment D : Heated for 8 hours at 1,080° C. and water-quenched. This treatment was used in an attempt to suppress precipitation of the $Ni_3(Ti,Al)$-phase during cooling, and also in order to ascertain the effect on the carbide reaction of variation in cooling rate from the normal solution-treatment temperature.

Samples of all the alloys were initially given solution treatment "A" and samples from the typical commercial alloy (Alloy No. 1, Table I) were also given treatments "B," "C" and "D." All samples were further heat treated, for times up to 5,000 hours, at temperatures in the range 500–1,100° C.

Methods of Examination

A minimum of $\frac{1}{16}$ in. was machined from all samples to remove material affected by oxidation during heat treatment. The concentration of precipitated phases, necessary before examination by X-ray diffraction techniques, was effected by electrolytic separation, in 10% HCl for the carbide phases and in 20% H_3PO_4 for the $Ni_3(Ti,Al)$-phase. X-ray diffraction examination of solid samples and of electrolytic residues was made by means of a G.E.XRD5 Geiger counter unit, using CuKα radiation.

Microsections from all samples were examined by optical metallographic techniques, after electrolytic etching in an aqueous solution of 10% glycerol and 5% hydrofluoric acid. For determining the rates of growth of the precipitates and the fine structure of the samples, a Metropolitan-Vickers EM.3 electron microscope was employed, using evaporated carbon replica techniques. Extraction replicas of the carbide phases were obtained by an immersion etch in a solution containing 100 ml. hydrochloric acid (conc.), 500 ml. nitric acid (conc.), 25 g. cupric chloride, and 25 g. ferric chloride, made up with water to one litre. For the extraction replicas of the $Ni_3(Ti,Al)$-phase an electrolytic etch of 10% orthophosphoric acid[6] was employed. Electron diffraction examination of selected areas of the extraction replicas revealed the nature and position of the various phases in the microstructure.

Experimental Results

General Observations

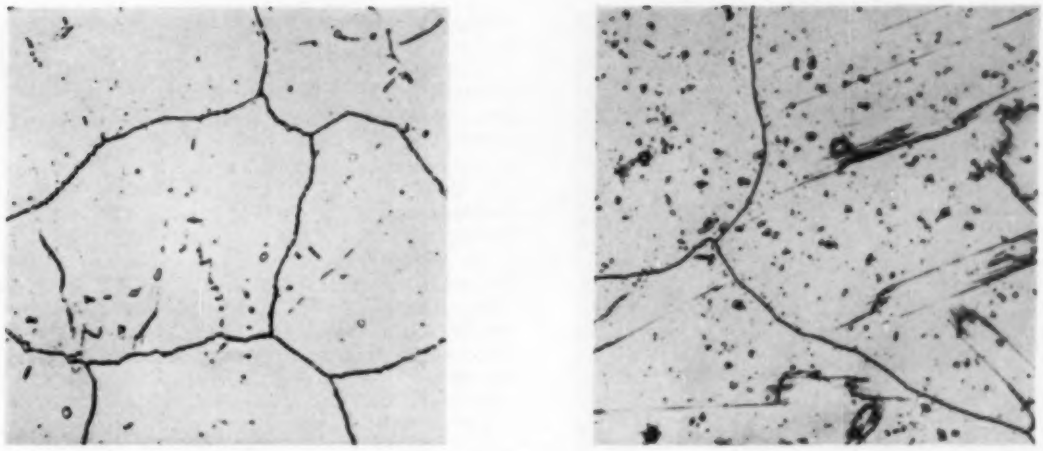
The minor phases found in the alloys were chromium-rich carbides of the Cr_7C_3- and $Cr_{23}C_6$-types ; two titanium carbonitride phases (Ti(C,N)) having slightly different lattice parameters ; the face-centred-cubic ordered phase based on Ni_3Al (referred to subsequently as $Ni_3(Ti, Al)$ since, in this structure, titanium can substitute extensively for aluminium) ; and a further phase which also appears to be of the Ni_3Al-type.

During heat treatment at temperatures between 500° C. and 1,100° C., after solution treatment at either 1,080° C. or 1,200° C., the Cr_7C_3 phase was formed

TABLE II.—COMPOSITION OF THE MATRIX AND OF THE Ni_3Al-TYPE PHASES

	Composition (wt. %)					
	Ni	Cr	Fe	Ti	Al	Others
Matrix*	75	19·8	0·32	2·27	—	~ 4·6
Second Ni_3Al-type phase* ..	70	11·0	0·3	Nil	—	~18·0
Typical $Ni_3(Ti,Al)$-type phase†	~80	6·2	—	9·5	5·2	—

* Microprobe analyses, published by courtesy of Mr. T. Mulvey, Associated Electrical Industries, Ltd., Aldermaston, England.
† Chemical analysis of precipitate, electrolytically separated.



(a) × 1,000 (b) × 520

Fig. 2.—Photomicrographs of samples of a heat of Nimonic 80A alloy heat treated for (a) 8 hours at 1,080° C. + 9 hours at 800° C.; and (b) 2 hours at 1,200° C. + 9 hours at 800° C.

initially, but at temperatures below approximately 1,050° C. was subsequently replaced by $Cr_{23}C_6$-phase. The crystallographic observations made on both chromium carbides were in good agreement with data given in the A.S.T.M. Index of X-ray Diffraction Patterns, although X-ray fluorescence analysis revealed that both chromium-rich carbides apparently contained approximately 5% nickel. The nickel may have been present in solid solution in the carbide, though it may, alternatively, have been matrix material of a particle size too small to give an X-ray diffraction pattern.

A considerable amount of the $Ni_3(Ti,Al)$-phase precipitated during air-cooling from the solution-treatment temperatures, but this precipitation was completely suppressed by water-quenching (Treatment D). X-ray fluorescence and chemical analyses of residues from the electrolytic separations in phosphoric acid indicated that the $Ni_3(Ti,Al)$-phase contained 5–10% chromium in solid solution and approximately 0·2% carbon, although, as in the case of nickel, chromium may have been finely divided matrix material. A typical analysis is included in Table II.

In samples heat treated for more than 700 hours at 1,000° C., or for longer periods at lower temperatures, e.g., approximately 5,000 hours at 700° C., an additional precipitate was developed, near the $Cr_{23}C_6$ particles at the grain boundaries and the Ti(C,N) particles within the grains, as illustrated in Figs. 1*a* and 1*b*. Since this precipitate could not be concentrated by the electrolytic or chemical methods of separation, a sample was examined by electron microprobe techniques, which showed that, by comparison with the matrix, the precipitate was depleted in chromium, nickel and titanium (see Table II). It is probable, therefore, that the balance was aluminium, which could not be detected with the microprobe analyser then available. The precipitate was therefore possibly of the Ni_3Al-type, containing less titanium than the normal face-centred-cubic $Ni_3(Ti,Al)$ precipitate primarily responsible for hardening.

X-ray diffraction examination of all carbide residues revealed the presence of varying proportions of the titanium carbonitride phase. This was found to consist of two face-centred-cubic phases of the TiC-type, one being carbon-rich, with a lattice parameter of 4·33Å, the other nitrogen-rich, with a lattice parameter of 4·24Å. The nitrogen-rich phase was not affected by any of the heat treatments applied, but partial solution of the carbon-rich phase occurred at high temperatures, with re-precipitation on ageing at lower temperatures. There is other evidence, however, not discussed here, that titanium carbonitride has no appreciable effect on the stress-rupture properties of this alloy.

Morphology of Precipitated Phases

The $Ni_3(Ti,Al)$-phase was taken into solution by treatment at either 1,080° C. or 1,200° C., but the solution temperature of the chromium-rich carbide phases depended, as would be expected, on the carbon content of the alloy. In alloys containing more than approximately 0·09% carbon which had been heat treated at 1,200° C., or in alloys containing more than approximately 0·03% carbon, heat treated at 1,080° C., some Cr_7C_3 globules remained undissolved, at the grain boundaries and within the grains.

During treatment at temperatures below 1,080° C. of alloys in which the Cr_7C_3-phase had not been completely dissolved during previous heat treatment, carbide precipitation tended to be concentrated as a continuous precipitate at the grain boundaries or on existing carbide nuclei within the grains (Fig. 2*a*). In alloys in which the first heat treatment had taken all chromium-rich carbides into solution, however, subsequent heat treatment at temperatures below 1,050° C. sometimes resulted in the ultimate formation of a considerable amount of intragranular $Cr_{23}C_6$-phase, which appeared as a "feathery" precipitate on the slip and twin planes of the matrix, Fig. 2*b*, in addition to normal continuous precipitation at the grain boundaries. The amount of intragranular $Cr_{23}C_6$-phase precipitated appeared to increase with the carbon content of the alloy, provided that all chromium-rich carbide had been dissolved during solution-treatment. The intragranular precipitate was most pronounced during subsequent treatment in the range 800°–950° C., and was only rarely observed in samples which had been treated at temperatures below

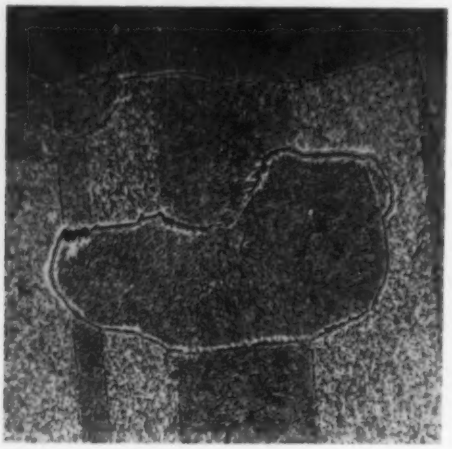


Fig. 3.—Photomicrograph of a sample of Nimonic 80A alloy, creep tested at 815° C. for 13,000 hours, illustrating an unusually well-defined zone adjacent to the grain boundary denuded of the $Ni_3(Ti,Al)$-phase. × 300

700° C. Precipitation of a chromium-rich carbide at the grain boundaries was frequently accompanied by the formation, adjacent to the boundary, of a zone which was denuded of the $Ni_3(Ti,Al)$ precipitate. Fig. 3 shows an unusually well-developed example of this phenomenon.

Crystallographic Relationships

Examination by X-ray diffraction and optical microscopy of matrix grains approximately 1 mm. in diameter, using a modification of the technique described by Barrett,[7] revealed that the main location of the intragranular $Cr_{23}C_6$ precipitate was along the (111) lattice planes of the matrix, with very occasional precipitation on the (110) planes. Examination, in the electron microscope, of carbide residues from electrolytic separations showed the presence of raft-like and triangular particles (Figs. 4*a* and 4*b*) which gave single-crystal electron diffraction patterns. Nearly all the electron diffraction patterns were from carbide particles extended in their (111) planes (Fig 5*a*), but occasional particles had a (110) orientation (Fig. 5*b*). It is reasonable to deduce, therefore, that the lattice planes of the intragranular precipitate of $Cr_{23}C_6$ were co-planar with those of the matrix.

It was similarly found, by the use of extraction replicas, that the $Ni_3(Ti,Al)$-phase precipitated along, and co-planar with, the (100) planes of the matrix: this finding confirms results obtained by Manenc.[8]

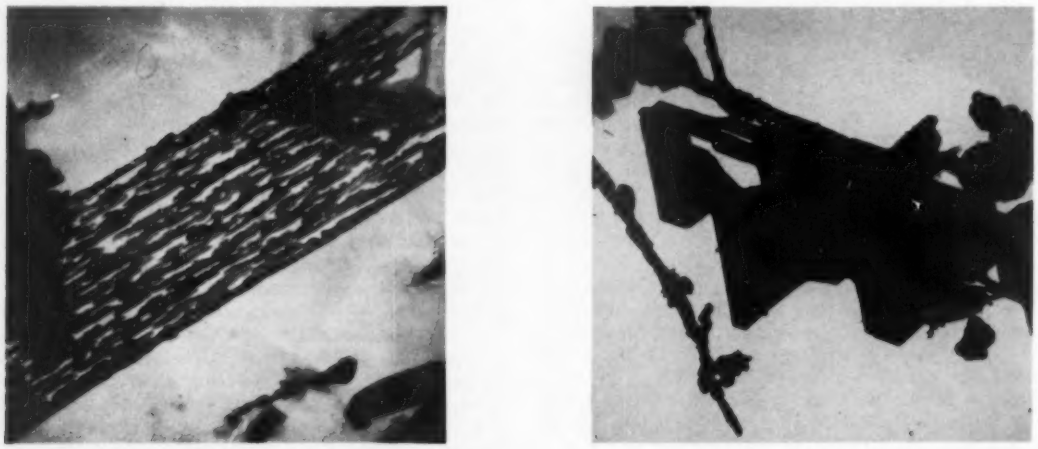
No orientation relationship could be detected between the matrix and the grain-boundary $Cr_{23}C_6$-phase, the Cr_7C_3-phase, or the Ti(C,N)-phases. As explained earlier, no extraction replicas of the second Ni_3Al-type phase could be obtained and it was not possible to define the orientation relationship with the matrix, but from metallographic evidence it appears likely that such a relationship exists (see Fig. 1*b*).

Effect of Heat-Treatment on Carbide Constitution in the Typical Commercial Alloy (Alloy No. 1, Table I)

The effect of heat treatment on the $Cr_7C_3 \rightarrow Cr_{23}C_6$ carbide transformation was studied in detail, using the production sample of Nimonic 80A: the results are illustrated in Fig. 6 in the form of isothermal transformation diagrams.

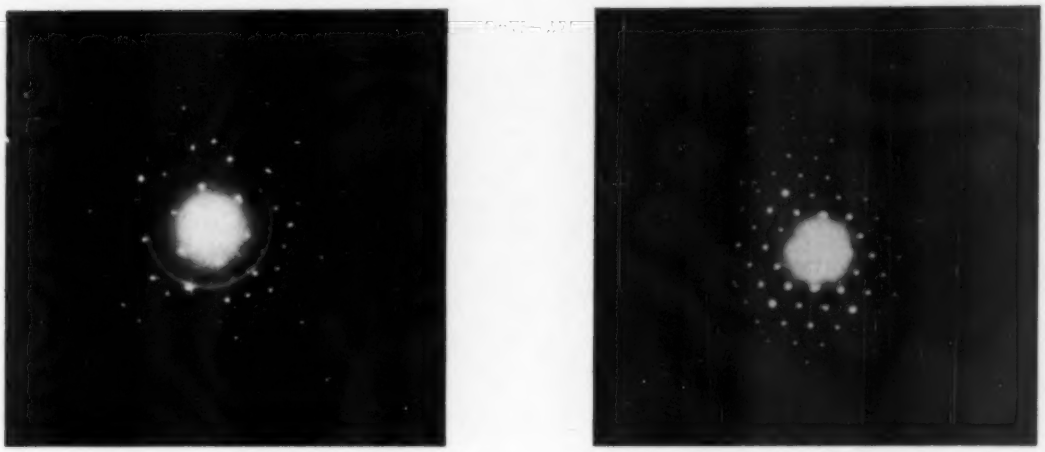
The chromium-rich carbide stable in the temperature range 1,050°–1,150° C. was of the Cr_7C_3-type. During re-treatment at any temperature below 1,050° C., the Cr_7C_3-phase was also the first chromium-rich carbide to be formed at that temperature irrespective of the previous solution treatment. As re-treatment proceeded, however, the Cr_7C_3-phase was progressively replaced by a carbide of the $Cr_{23}C_6$-type. In samples which had previously been solution-treated at 1,080° C., metallographic, X-ray, and electron diffraction examination revealed that the formation of $Cr_{23}C_6$ occurred mainly at the grain boundaries and only slightly within the grains, whereas in samples which had been solution-treated at 1,200° C., a considerable amount of intragranular $Cr_{23}C_6$-phase was developed (Figs. 2*a* and 2*b*).

Fig. 6 demonstrates that the initial rate of carbide



(a) × 25,000 (b) × 25,000

Fig. 4.—Electron microscope shadowgraphs of the $Cr_{23}C_6$-phase extracted from Nimonic 80A alloy, showing the presence of particles as (a) "rafts," and (b) triangles.



(a) (b)

Fig. 5.—Electron diffraction photographs from $Cr_{23}C_6$ particles in the form of "rafts," showing (a) a (111), and (b) a (110) orientation.

reaction to form $Cr_{23}C_6$, was dependent on the prior solution-treatment. After treatment B (8 hours at 1,080° C., air-cool) the Cr_7C_3-phase was not completely dissolved and the effect of this pre-existing Cr_7C_3-phase was to reduce the initial rate of formation of $Cr_{23}C_6$-phase during subsequent heat treatment, as compared with the rate of reaction in samples solution-treated at 1,200° C. (Treatment A). Treatment C (8 hours at 1,080° C., air-cool, + 24 hours at 850° C., air-cool) produced a structure in which approximately 50% of the carbide was of the $Cr_{23}C_6$-type. The time required to achieve carbide transformation on re-treatment at temperatures below 850° C. was apparently slightly longer than for samples which had received no prior treatment at 850° C.; for example, samples which had undergone solution-treatment C still contained approximately 5% of the Cr_7C_3-phase after re-treatment for 2,000 hours at 700° C., whereas in samples which had been solution-treated for 8 hours at 1,080° C. and air-cooled, no Cr_7C_3-phase was present after similar re-treatment.

Effect of Internal Stress on the Morphology of the $Cr_{23}C_6$-Phase

Internal stress produced by water-quenching from the solution-treatment temperature appeared to alter the morphology of the $Cr_{23}C_6$-phase formed during re-treatment in the range 600°–800° C. Thus, the $Cr_{23}C_6$-

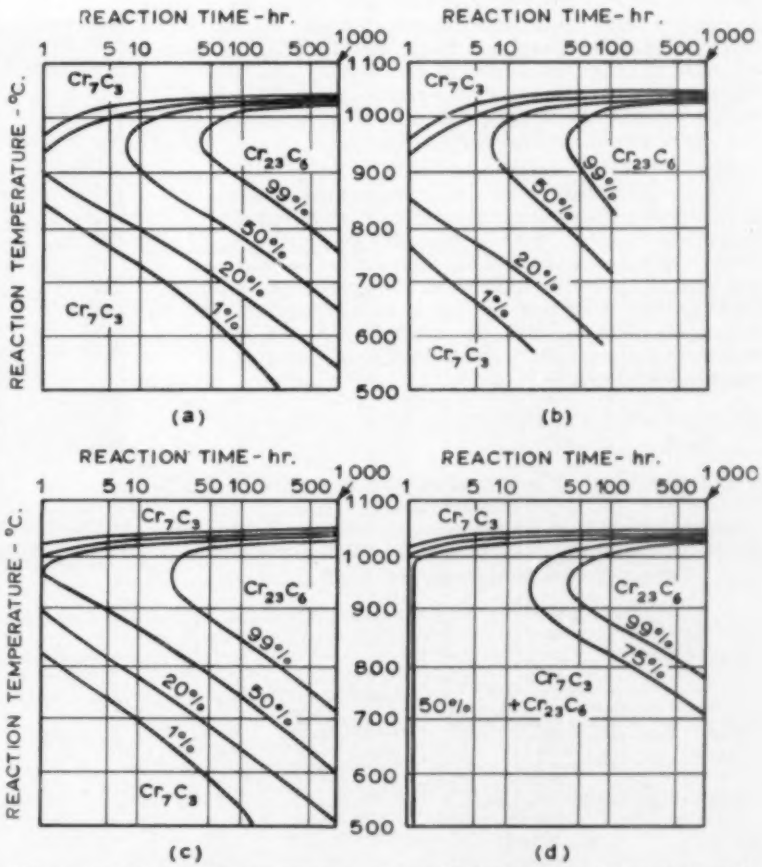
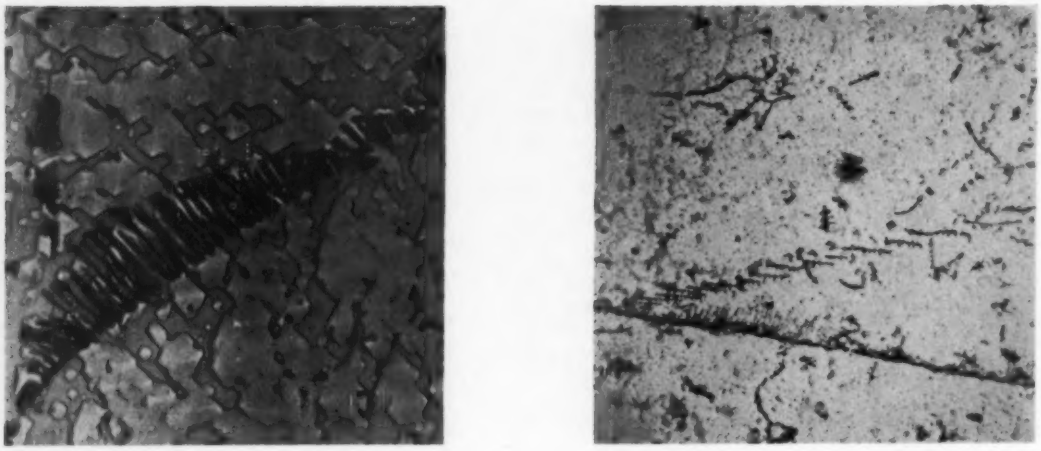


Fig. 6.—Reaction-time/temperature curves for Alloy No. 1 (Table I) during various heat treatments: (a) 8 hours at 1,080° C., air-cooled; (b) 8 hours at 1,080° C., water-quenched; (c) 2 hours at 1,200° C., air-cooled; (d) 8 hours at 1,080° C., air-cooled + 24 hours at 850° C., air-cooled.



(a) × 12,500 (b) 20,000

Fig. 7.—Electron micrographs of extraction replicas of the $Cr_{23}C_6$-phase from Nimonic 80A, showing (a) cellular precipitation, and (b) precipitation, apparently on dislocation sites. The samples were water-quenched from 1,080° C. and further heat treated for 27 hours at 700° C.

phase tended to appear in a cellular form at the grain boundaries (Fig. 7*a*), in a manner similar to that observed in other alloys by Hagel and Beattie.[9] In addition, a larger proportion of the carbide was produced within the grains on slip-planes, presumably at the sites of dislocation "pile-up" near grain boundaries and titanium carbonitride particles (Fig. 7*b*).

The presence of intragranular $Cr_{23}C_6$-phase at dislocation sites and in cellular form near grain boundaries was observed also in samples which had been creep-tested at temperatures below 800° C. (Fig. 8), after treatment comprising 8 hours at 1,080° C., followed by air-cooling, and then by ageing for 16 hours at 700° C. This form of $Cr_{23}C_6$ precipitation was only rarely observed, however, in samples which had been air-cooled from the solution-treatment temperature and re-treated or creep-tested at temperatures above 800° C.

Effect of Variation in Heat Treatment on the $Ni_3(Ti,Al)$-Phase

The effect of rate of cooling after solution-treatment of 8 hours at 1,080° C., on precipitation of the $Ni_3(Ti,Al)$-phase during further heat treatment, is shown by the results in Table III. Water-quenching from 1,080° C. completely suppressed precipitation of $Ni_3(Ti,Al)$ during

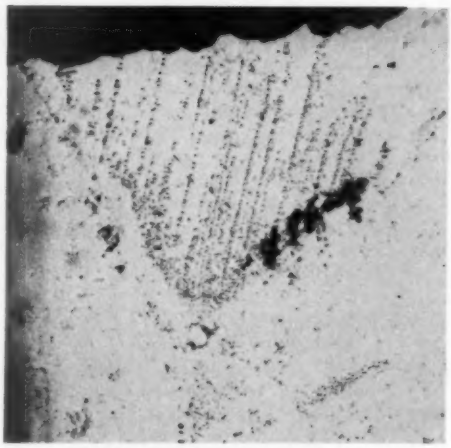


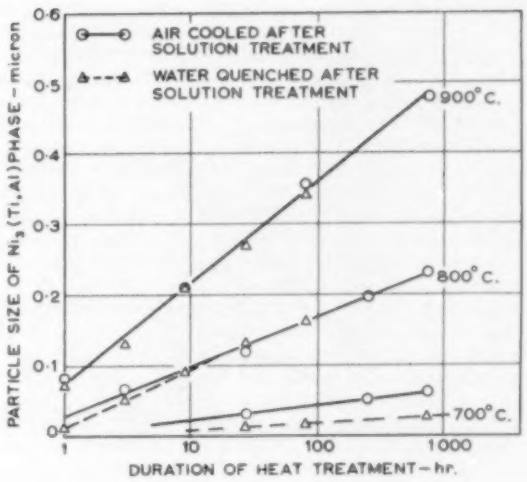
Fig. 8.—Electron micrograph of an extraction replica of the $Cr_{23}C_6$-phase showing precipitation, apparently on dislocation sites, in a sample creep-tested at 650° C. and 30 tons/sq. in. for 275 hours. × 3,000

TABLE III.—EFFECT OF HEAT TREATMENT ON THE PRECIPITATION OF THE $Ni_3(Ti,Al)$-PHASE IN ALLOY NO 1 OF TABLE I

Solution Heat Treatment			Ageing Temperature (° C.)	Duration of Ageing (hr.)									
				0		1		3		16		81	
Time (hr.)	Temperature (° C)	Cooling Method		Lattice Parameter (Å)	Weight of Extract (%)*	Lattice Parameter (Å)	Weight of Extract (%)*	Lattice Parameter (Å)	Weight of Extract (%)*	Lattice Parameter (Å)	Weight of Extract (%)*	Lattice Parameter (Å)	Weight of Extract (%)*
8	1,080	W.Q.	700	—	Nil	—	Nil	—	Nil	3·57	3·6	3·575	9·1
8	1,080	A.C.	700	3·583	8·0	3·583	8·5	3·582	8·5	3·580	9·0	3·581	9·1
8	1,080	W.Q.	800	—	Nil	3·579	11·1	3·580	12·4	3·581	13·3	3·581	13·4
8	1,080	A.C.	800	3·583	8·0	3·581	11·9	3·581	12·8	3·582	13·4	3·582	13·4
8	1,080	W.Q.	900	—	Nil	3·582	9·4	3·583	12·1	3·584	8·3	3·584	5·0
8	1,080	A.C.	900	3·583	8·0	3·585	9·7	3·585	12·0	3·584	8·2	3·584	4·8

W.Q. = Water-quenched.
A.C. = Air-cooled.
* = Weight of $Ni_3(Ti,Al)$-phase expressed as a percentage of the weight of the alloy from which it was separated.

Fig. 9.—Rate of increase of particle size of $Ni_3(Ti,Al)$-phase in Alloy No. 1 (Table I) during heat treatment at 700° C., 800° C., and 900° C.


AIR COOLED AFTER SOLUTION TREATMENT
WATER QUENCHED AFTER SOLUTION TREATMENT
900° C.
800° C.
700° C.
PARTICLE SIZE OF Ni3(Ti,Al) PHASE – micron
DURATION OF HEAT TREATMENT – hr.

cooling, although during air-cooling 8% by weight of the alloy was precipitated, apparently as $Ni_3(Ti,Al)$. The effect of variation in ageing temperature on the lattice parameter of the $Ni_3(Ti,Al)$-phase is shown in Table III, which indicates that partial re-solution of the $Ni_3(Ti,Al)$-phase may occur after heat-treatment for more than 3 hours at 900° C. Complete solution did not, however, occur in this alloy at temperatures below 950° C.

The partial re-solution of the $Ni_3(Ti,Al)$-phase may be due to increased capacity of the matrix for dissolving titanium and aluminium caused by the rapid precipitation of the chromium-rich carbide $Cr_{23}C_6$. It is estimated that this carbide precipitation would reduce the chromium content of the matrix by approximately 1%, with resulting increase in capacity for solution of titanium and aluminium.[3] Because no attempt was made to obtain complete homogeneity in the samples, however, this re-solution may be related merely to local segregation.

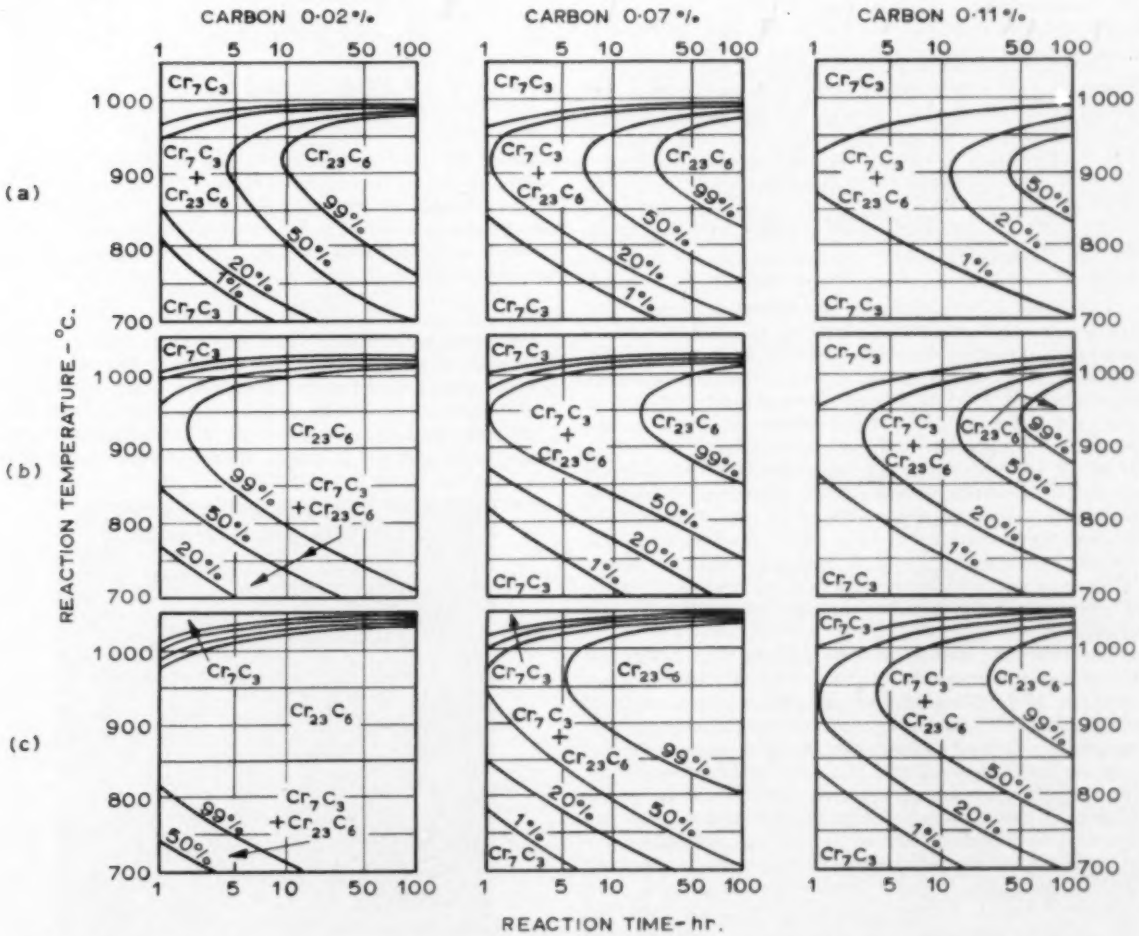


Fig. 10.—Reaction-time/temperature curves for alloys with differing carbon, titanium and aluminium contents: (a) titanium + aluminium = 2·7%; (b) titanium + aluminium = 3·7%; and (c) titanium + aluminium = 4·5%. Carbon contents are stated at the top of the diagram.

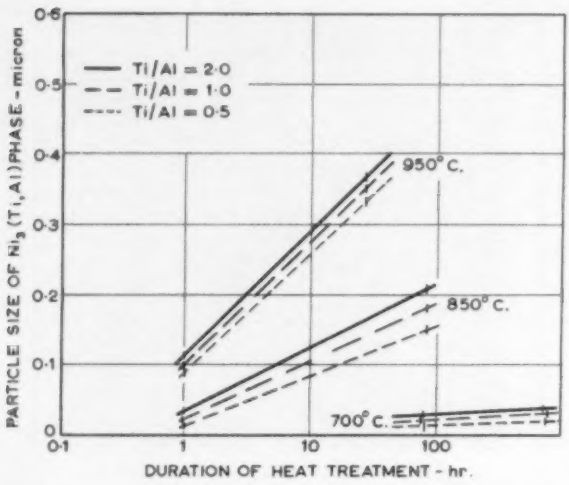


Fig. 11.—Rate of increase of particle size of $Ni_3(Ti,Al)$-phase in alloys with differing titanium and aluminium contents.

The rates of increase of particle size of the $Ni_3(Ti,Al)$-phase on heat treatment at temperatures of 700°, 800° and 900° C., after both water-quenching and air-cooling from the solution-treatment temperature, are given in Fig. 9, showing that the particle-size/ageing-time curves for water-quenched and air-cooled samples are coincident after ageing for less than 1 hour at 900° C. and/or 4 hours at 800° C., but that at 700° C. they do not coincide, even after 81 hours.

Effect of Variation in Alloy Composition on Constitution

The effect of variations in the carbon, titanium and aluminium contents of the alloys, on the carbide phases precipitated during heat treatment, is shown by the transformation diagrams of Fig. 10. As the titanium plus aluminium content was increased from 2·7% to 4·5%, the temperature above which the $Cr_{23}C_6$-phase tended to disappear rose from approximately 990° C. to 1,050° C. Variation in the titanium : aluminium ratio appeared, however, to have little effect on the carbide reaction. As the carbon content of the alloy was increased from 0·02 to 0·11%, the initial rate of the carbide reaction $Cr_7C_3 \rightarrow Cr_{23}C_6$ was appreciably reduced. With very low carbon content (approximately 0·01%), however, the only carbides detected were Ti(C,N) and $Cr_{23}C_6$.

The effect of variation in composition on the $Ni_3(Ti,Al)$-phase was investigated by measuring the lattice parameter at 20° C. of material separated in a phosphoric acid electrolytic cell (Table IV), and by determining particle size, using electron microscopic examination of extraction replicas (Figs. 11 and 12). As would be expected, the solution temperature of the $Ni_3(Ti,Al)$-phase (Table IV), and the amount of precipitate, were influenced by the titanium + aluminium content of the alloy, but were little affected by variation in the titanium: aluminium ratio. These results are in accord with published data.[3] Values given in Table IV indicate that the lattice parameter of the $Ni_3(Ti,Al)$-phase was dependent mainly on the titanium : aluminium ratio of the alloy, and was slightly modified by the temperature at which precipitation occurred, but that it was unaffected by the total titanium plus aluminium content, or by the carbon content of the alloy. The rate of growth of the $Ni_3(Ti,Al)$-phase during ageing appeared to depend more on variations of lattice parameter of the precipitate than on that of the matrix, even though the two are of the same order.

TABLE IV.—EFFECT OF VARIATION IN COMPOSITION AND HEAT TREATMENT ON THE LATTICE PARAMETERS OF THE MATRIX AND THE $Ni_3(Ti,Al)$-PHASES

Alloy No.	Ti:Al Ratio	Ti+Al (wt. %)	C (wt. %)	$Ni_3(Ti,Al)$-Phase Parameter (Å) 81 hr. at 850° C.	27 hr. at 950° C.	750 hr. at 700° C.	Matrix Parameter (Å) As solution-treated	81 hr. at 850° C.
2	2·02	2·5	0·01	••	••	N.D.	3·564	3·564
11	3·34	2·4	0·08	••	••	N.D.	3·564	3·564
20	2·02	2·6	0·12	••	••	3·583	3·564	3·564
3	1·99	3·9	0·02	3·584	N.D.	N.D.	3·569	3·567
12	2·03	3·9	0·07	3·584	3·587	N.D.	3·568	3·566
21	2·14	3·9	0·14	3·585	N.D.	3·584	3·568	3·566
4	2·20	4·5	0·05	3·586	N.D.	N.D.	3·570	3·566
13	2·12	4·6	0·09	3·586	3·587	N.D.	3·571	3·567
22	2·24	4·6	0·12	3·585	N.D.	N.D.	3·570	3·566
5	1·05	2·6	0·03	3·581	••	N.D.	3·564	3·564
14	1·13	2·7	0·08	3·581	••	N.D.	3·565	3·565
23	1·10	2·6	0·15	3·581	••	N.D.	3·564	3·564
6	1·07	3·6	0·01	3·580	•	N.D.	3·566	3·565
15	1·06	3·6	0·08	3·580	•	3·578	3·566	3·566
24	1·07	3·8	0·13	3·580	N.D.	N.D.	3·567	3·566
7	1·06	4·3	0·01	3·581	3·582	N.D.	3·571	3·566
16	1·04	4·5	0·07	3·580	N.D.	N.D.	3·572	3·567
25	1·12	4·5	0·12	3·579	N.D.	N.D.	3·570	3·566
8	0·35	2·1	0·05	••	••	N.D.	3·562	3·562
17	0·61	2·8	0·07	••	••	N.D.	3·564	3·564
26	0·35	3·0	0·09	3·574	••	N.D.	3·565	3·565
9	0·54	3·8	0·03	3·574	N.D.	N.D.	3·568	3·566
18	0·59	3·6	0·07	3·574	•	3·572	3·566	3·565
27	0·45	3·7	0·09	3·574	•	N.D.	3·566	3·565
10	0·55	4·3	0·03	3·574	3·577	N.D.	3·570	3·567
19	0·60	4·5	0·05	3·575	N.D.	N.D.	3·571	3·567
28	0·55	4·4	0·11	3·573	N.D.	N.D.	3·570	3·567

N.D. = Not determined.
•• = No $Ni_3(Ti,Al)$-phase extracted.
• = Only trace $Ni_3(Ti,Al)$-phase extracted.

Discussion of Results

Interpretation of the results obtained in this investigation and, in particular, of the possible influence of the precipitation phenomena on the performance of Nimonic 80A in service, must necessarily be somewhat speculative.

It will be noted that the $Ni_3(Ti,Al)$-phase and the $Cr_{23}C_6$-phase have the same crystal structure as the

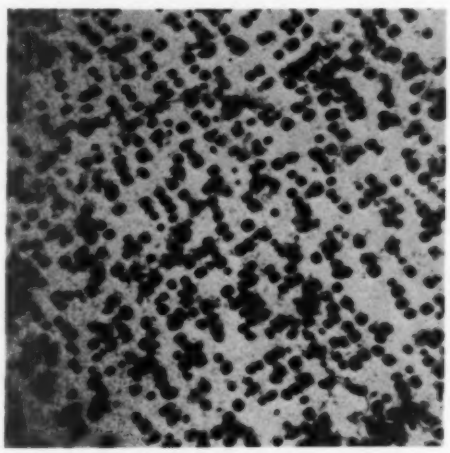


Fig. 12.—Electron micrograph of a typical extraction replica of the $Ni_3(Ti,Al)$-phase. × 9,000

matrix (face-centred-cubic), with lattice parameters, respectively, of approximately 3·58 and 10·63Å, which are near-multiples of that of the matrix, 3·57Å. It has been shown that definite orientation relationships exist between the lattice planes of the matrix and those of the precipitates of these phases.

The morphology of the precipitates in the matrix appears to indicate that the close matching of lattice planes is maintained at the temperature of formation of the precipitates, and it may be supposed that, for planes formed at relatively high temperatures, the interface with the matrix would be in the form of a regular dislocation array, i.e., a low-angle boundary. The surface energy at such an interface will be low, and there will be little incentive for growth. This may well account in large measure for the low rate of growth of $Ni_3(Ti,Al)$ particles illustrated in Figs. 9 and 11.

For many applications at high temperatures, resistance to creep deformation is not the most essential property, time-to-rupture assuming greater importance. It has been pointed out[5] that, if an unfavourable carbide distribution is present, fracture can occur during creep testing at a relatively small extension, so that life may be very short despite a low creep rate. This is liable to occur readily in alloys containing less than about 0·03% carbon. Conversely, in alloys containing more than about 0·10% carbon, high creep rates and excessive extension at fracture are frequently associated with a short life, although it is sometimes possible to obtain good creep properties in a high-carbon alloy by means of specially adapted heat treatment.

From the metallographic evidence available it appears that the early precipitation of a chromium-rich carbide at the grain boundaries leads to a chromium concentration gradient near the boundary. It is known[4] that a decrease in the chromium content of the alloy leads to an increase in the solubility of titanium and aluminium in the matrix. As a result there is formed, adjacent to the grain boundaries, a zone in which the solubility of titanium and aluminium is greater than in the interior of the grains. This zone therefore contains less $Ni_3(Ti,Al)$ precipitate, and can more readily permit the relaxation of local stresses which, during creep, concentrate at the grain boundaries and grain corners. The chromium concentration gradient will tend to be maintained by any reaction involving a migration of chromium to the boundary. The $Cr_7C_3 \rightarrow Cr_{23}C_6$ reaction and any treatment which tends to reduce the rate of carbide reaction favour maintenance of this zone.

It is indeed known that, after prolonged heat treatment, when the carbide reaction has ceased, the zone denuded of $Ni_3(Ti,Al)$ is still maintained. Since uniformity of chromium distribution is probably achieved at such long times, it is to be presumed that when this stage is reached the excess titanium and aluminium have already migrated away from the boundaries. In alloys containing less than 0·03% carbon, the amount of chromium carbide precipitated is insufficient to develop a continuous denuded zone at the grain boundaries, and it is probable that this accounts for the reduced ductility and premature brittle failure characteristic of low-carbon alloys. It is known that on heat treatment of alloys containing more than 0·10% carbon, precipitation of carbide at the grain boundaries is heavy and the $Ni_3(Ti,Al)$-denuded zones become extremely wide. It is reasonable, therefore, to suppose that this wide, weak zone promotes the excessive creep ductility found with high-carbon alloys.

The reduction in ductility[5] observed after creep testing at 700° C., in alloys water-quenched from " intermediate temperatures " above 1,050° C., may well result from the locking of dislocations by precipitation of $Cr_{23}C_6$ on dislocation sites during ageing at 700° C. No metallographic evidence was found to suggest that the onset of fissures at the grain boundaries during creep was associated with any particular type of precipitate : this observation tends to confirm the results of Bückle and Poulignier,[10] who found that internal cracks are rarely associated with cellular precipitation. It is possible that pronounced precipitation of the cellular type is merely symptomatic of an internal-stress system which could lead to dislocation locking and resultant loss of stress-rupture ductility. It seems unlikely that the presence of any particular phase, such as $Cr_{23}C_6$, would cause premature failure. It is important, however, that the heat treatment applied should be such as to ensure that the carbide phases are formed at the grain boundaries and not at dislocation sites within the grains.

The importance of a satisfactory distribution of chromium carbide was clearly demonstrated by Betteridge and Franklin,[5] who found that an excellent combination of creep life and ductility was obtained after solution-treatment at 1,200° C., followed by an intermediate treatment at 1,000° C. and final ageing at 700° C. However, the simplified treatment of heating for 8 hours at 1,080° C., followed by air-cooling, and then 16 hours at 700° C., was found to be a satisfactory practical compromise to meet conflicting requirements for creep-resistance and ductility. Both these heat treatment schedules induce the formation of a chromium-carbide precipitate at the grain boundaries coupled, presumably, with a chromium-impoverished region adjacent to the grain boundaries.

To sum up, the evidence presented suggests that the useful properties of Nimonic 80 and related alloys arise from a strengthening of the matrix by general precipitation of the $Ni_3(Ti,Al)$-phase, combined with the formation, at the grain boundaires, of zones which are sufficiently weak to permit relaxation of local stresses. These zones are induced in the alloys by initial precipitation of Cr_7C_3-phase at the grain boundaries, and are maintained by the subsequent carbide reaction $Cr_7C_3 \rightarrow Cr_{23}C_6$.

CONCLUSIONS

(1) Of the five minor phases observed, $Cr_{23}C_6$, $Ni_3(Ti,Al)$, and possibly the second Ni_3Al-type phase, precipitate within the grains in an orientation identical with that of the matrix.

(2) In an alloy which has undergone a typical solution-treatment, the first chromium carbide to precipitate during subsequent heat treatment in the range 500°–1,150° C. is of the Cr_7C_3-type, and on further heat treatment, at temperatures below 1,050° C., this phase is progressively replaced by a carbide of the $Cr_{23}C_6$-type.

(3) The carbide reaction, $Cr_7C_3 \rightarrow Cr_{23}C_6$, is accelerated by internal strain, by low carbon content, or by high total titanium plus aluminium content : it is retarded by pre-existing Cr_7C_3-phase, by high carbon, or by low total titanium plus aluminium content.

(4) The solution temperature of the $Cr_{23}C_6$-phase rises

with increase in total titanium plus aluminium content of the alloy.

(5) The marked development of $Cr_{23}C_6$ precipitate on dislocation sites near the grain boundaries, or as cellular precipitate at grain boundaries, is associated with the presence of internal stress.

(6) The lattice parameter and the rate of growth of the $Ni_3(Ti,Al)$-phase increase with the titanium : aluminium ratio of the alloy, and with rise in the temperature of precipitation. It is independent of the total titanium plus aluminium content of the alloy.

(7) Water-quenching from the solution temperature prevents $Ni_3(Ti,Al)$ precipitation during cooling and increases the rate of growth during subsequent ageing, but the particle size ultimately attained is similar to that of an air-cooled and aged alloy.

(8) There is no evidence to suggest that the $Cr_{23}C_6$-phase, in either normal or cellular form, has a deleterious effect on the fracture mechanism of the alloys.

Acknowledgments

The author is indebted to The International Nickel Co. (Mond), Ltd., for permission to publish this paper, and wishes to thank his many colleagues: in particular, Mr. A. W. Franklin, Dr. C. A. Clark and Dr. D. W. Wakeman, for advice and assistance.

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Tin Conference in Paris

THE tenth Journée de l'Etain in Paris was held last month at the Maison de la Chimie, 28 bis, rue Saint-Dominique, Paris 7ème. The general theme of the conferences was " Tin-Base Bearings," with particular reference to the manufacture of tin-base bearings for larger engineering units. The chairman was Professeur P. Bastien, Director of Research and Professor at l'Ecole Centrale des Arts et Manufactures. Of the four papers comprising the conference programme, two were presented by members of the staff of the Tin Research Institute.

In the opening lecture on the choice of a bearing metal, Mr. W. R. Lewis, assistant director, dealt with the fundamental requirements of bearing alloys in general, discussing in turn oil-retaining quality, embeddability for grit and foreign particles, immunity from seizure, fatigue resistance, and dimensional stability.

Of all the possible materials, tin-based alloys had proved most successful for all applications, except for the modern very small and extremely highly loaded high-speed backed bearings of motor cars. In the last three or four years even this deficiency in the range of tin-based bearings had been overcome by the development of the aluminium-tin bearing alloy containing 20% of tin.

In the general engineering field where it was not necessary to subject bearings to such extreme stresses, the tin-base babbitt alloys continued to dominate the field on the grounds of general suitability and safety under every variety of working conditions.

With a view to facilitating the selection of the right tin-base bearings, and in the interest of standardisation, the British Standards Institution had recently published for the first time specifications covering the nine bearing alloys, ranging in tin content from 90% downwards and including two in which lead was the predominant metal. Practically every engineering requirement could be met from one or other of these recommended alloys.

In his address dealing with the effect of preparation and tinning procedures on the adhesion of white metal bearing linings to steel and cast iron shells, Dr. W. E. Hoare, assistant director, said that a sound bond was necessary in order to give good thermal conductivity, proper reinforcement of the lining by the shell, and therefore good resistance to mechanical failure during use.

Steel shells could be prepared by normal acid pickling but cast iron shells required the use of different procedures in order to overcome the effect of graphite present in the structure of cast iron. The various operations of preparation and tinning were described, and the levels of adhesion obtainable by different procedures were indicated.

The preparation, tinning, and lining of large bearing shells for heavy-duty machinery should be a well-planned and well-controlled metallurgical operation. Laboratory investigations had resulted in the development of preferred procedures, and modern engineering plants were making increasing use of these new and improved techniques.

Wellman Contracts

ORDERS amounting to approximately £2 million have recently been placed with The Wellman Smith Owen Engineering Corporation, Ltd., for steelworks plant and equipment. It is noteworthy that these contracts include rolling mill plant to the value of £750,000 (approx.) secured under the collaboration agreement entered into a short time ago between Wellman and Schloemann A.G., the well known German rolling mill engineers.

Recent Wellman contracts also include an LD/AC oxygen steel making unit for Stewarts and Lloyds, Ltd., Corby, under the Wellman-Voest agreement, including the supply of heavy duty cranes. Wellman have also received a £270,000 contract from Shelton Iron & Steel, Ltd., of Stoke-on-Trent, for mill cranes required on urgent delivery to be available for erection and servicing of their new rolling mills.

Pressing and Sintering of Nickel Brasses

By J. Wilcock, B.Eng., Ph.D., A.I.M. and R. J. Woolfall

Powder Metallurgy Limited, London

Sintered nickel brass components can usefully replace standard brass powder parts when certain colour and/or corrosion resistance requirements are to be met. In the following pages the optimum processing conditions are given and the effect on processing and properties of additions of lead, phosphorus and iron discussed.

WHILE considerable information is available describing the pressing and sintering of pre-alloyed brass powders, very little has been published with regard to "nickel silvers," in which part of the zinc content is replaced by nickel. The presence of nickel imparts good corrosion resistance and a "silver" appearance to the material—hence the name "nickel silver"—characteristics which become more pronounced with increasing nickel content. Nickel silvers are alloys of copper, nickel and zinc, which form homogeneous solid solutions comparable to alpha brass. It seems, therefore, more appropriate to refer to these materials as nickel brasses, a policy which has been adopted in this paper.

Sintered nickel brass components are fabricated under conditions similar to those used for standard brass powder parts, and usefully replace the latter when colour and/or corrosion-resistant properties are required. The sintered material is used for various small parts in the automobile and aircraft industries, and in domestic food equipment. It is found that economics favour the use of a nickel brass compared with an electroplated standard brass component. An interesting potential use for sintered nickel brass is the manufacture of key blanks for use with tumbler locks. For this application, corrosion-resistant compacts possessing good torsional strength with a maximum resistance to deflection are required, and alloys containing iron and phosphorus have been developed to meet these requirements.

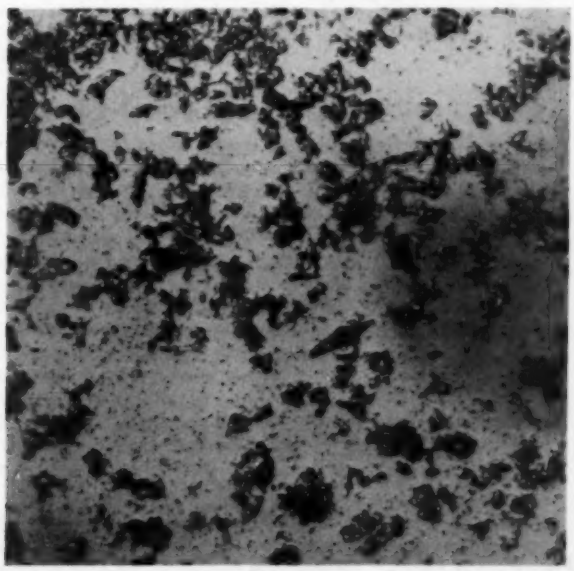


Fig. 1.—Atomised nickel brass powder. ×33

Ideally, sintered parts manufacturers aim to produce components which do not require further processing, but design features frequently make final machining operations necessary. The incorporation in brass of small quantities of lead to provide free-cutting properties is standard practice, and the effect of a 2% lead addition on the pressing and sintering of a 60/10/30 nickel brass has been examined in the work now reported.

This paper describes the pressing and sintering behaviour of a series of 10% nickel brasses. Comparisons with the properties obtainable from standard brass powder components are also made.

Experimental

Properties of Powders

The atomised pre-alloyed nickel brass powders in this investigation were produced by Powder Metallurgy, Ltd., a division of F. W. Berk & Co., Ltd. The chemical analyses and physical properties of these powders are given in Table I: they consist of irregularly-shaped particles as can be seen from Fig. 1.

Procedure

To facilitate the pressing operation, all powders were premixed with lubricant in a double cone blender for 30 minutes at a temperature of approximately 60° C. Compaction was carried out by the method described by Bell *et al.** to produce:—

(*a*) 1 in. diameter cylinders and bushes.

(*b*) shaped tensile test pieces to B.S. 2590.

(*c*) rectangular test pieces 1·75 × 0·25 × 0·1 in.

To decompose and remove the lubricant, preheating to 150° C. was carried out in air for 15 minutes. The green compacts were then dusted with alumina powder and placed in stainless steel boats with a fitted lid, and sintered in a resistance-wound tube furnace under a 3 : 1 hydrogen-nitrogen atmosphere. The required sintering temperature was reached after 15 minutes and maintained for a further 30 minutes. The temperature of the hot zone during this operation was controlled to within ± 5° C. Cooling to room temperature took place

* *Metallurgia*, 1958, **58**, 233.

TABLE I.—CHEMICAL ANALYSIS AND PHYSICAL PROPERTIES OF POWDERS USED

Powder No.		1		2	3	4	5	6	7	8
Chemical Analysis (%):	Cu	59·1		48·91	61·06	70·00	59·94	61·66	59·04	58·1
	Ni	10·02		9·5	9·00	10·1	9·86	9·62	9·75	10·05
	Pb	0·89			—	0·02	—	—	—	2·17
	P	0·68			—	0·01	—	0·51	0·78	—
	Fe	—		0·15	—	0·12	1·47	1·44	2·15	0·04
	Sn	0·02		0·02	0·02	0·02	0·02	0·02	0·02	0·02
	Zn	bal.		bal.	bal.	bal.	bal.	bal.	bal.	bal.
Screen Analysis (wt. %)		(a)	(b)							
	+100	Tr.	—	Tr	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
	100/200	13·3	Tr.	15·3	20·1	18·3	10·9	16·5	27·4	6·2
	200/300	22·8	25	17·4	17·0	16·4	19·7	20·7	16·5	9·8
	−300	63·9	75	67·3	62·9	65·3	69·4	62·8	56·1	84·0
Apparent Density (Hall) (g./ml.)		3·00		2·63	2·94	2·93	2·84	3·06	3·14	3·18
Flow Factor (50 g.) (sec.)		27·7		29·4	26·4	26·5	27·6	23·2	23·3	22·0

during a period of 60 minutes under the same reducing atmosphere conditions.

Determinations of green density, sintered density, dimensional change and radial crushing strength were made in the usual manner. Tensile strength was determined according to the procedure outlined in B.S. 2590, using a Hounsfield Tensiometer, and the elongation was measured from the 1 in. gauge length of these specimens. Brinell hardness tests were carried out by applying to the specimen a 10 mm. ball under a load of 500 kg. for 15 seconds.

During this investigation every attempt has been made to use conditions which are easily attainable in production-scale operation.

Results

It is convenient to consider the results in two sections. The first section deals with the effect of processing variables, whilst in the second part the influence of compositional variables is studied on compacts processed under optimum conditions of lubrication and sintering temperature.

I. Influence of Powder Characteristics and Compacting and Sintering Conditions on Mechanical Properties of 60% Copper–10% Nickel–30% Zinc Alloy.

This study was carried out with a standard production powder (alloy powder No. 1), details of which are given

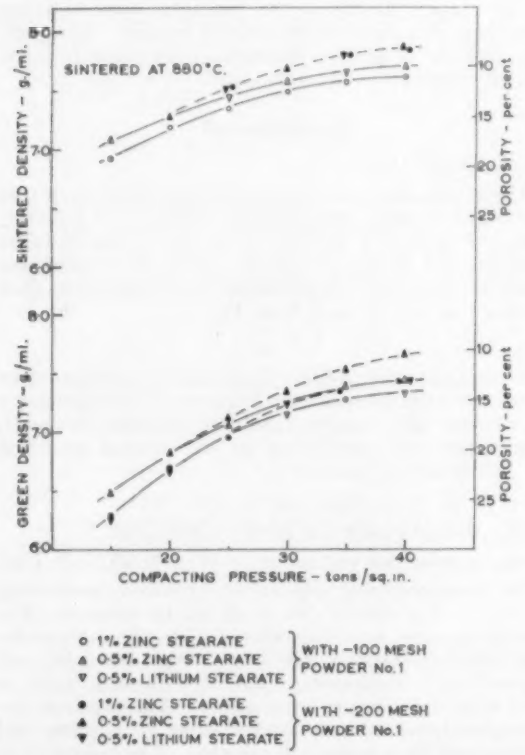

SINTERED AT 880°C.
SINTERED DENSITY - g./ml.
GREEN DENSITY - g./ml.
POROSITY - per cent
COMPACTING PRESSURE - tons/sq.in.
○ 1% ZINC STEARATE
▲ 0·5% ZINC STEARATE
▼ 0·5% LITHIUM STEARATE
WITH −100 MESH POWDER No.1
● 1% ZINC STEARATE
▲ 0·5% ZINC STEARATE
▼ 0·5% LITHIUM STEARATE
WITH −200 MESH POWDER No.1

Fig. 2.—The effect of compacting pressure and lubricant on green and sintered densities of 60/10/30 nickel brass. (Powder No. 1).

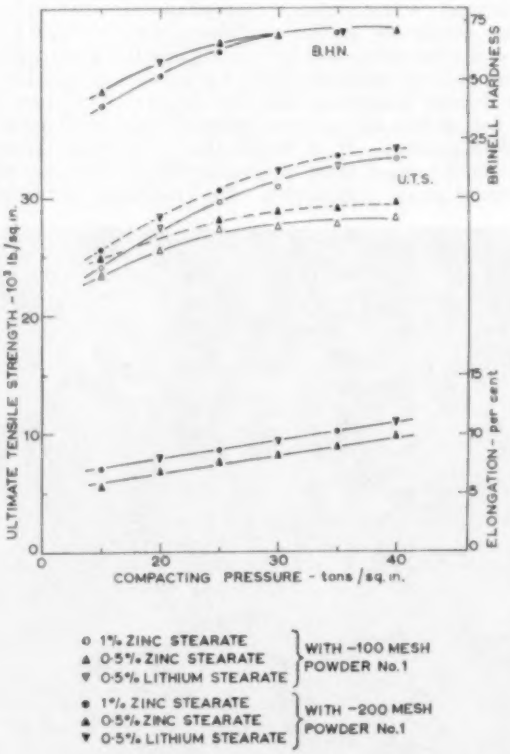


Fig. 3.—The effect of compacting pressure and lubricant on mechanical properties of 60/10/30 nickel brass (Powder No. 1) sintered at 880° C.

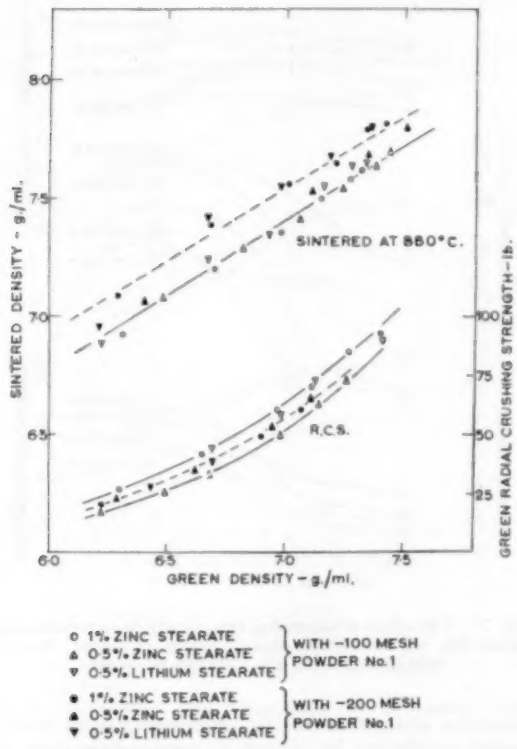

SINTERED DENSITY - g./ml.
GREEN RADIAL CRUSHING STRENGTH - lb.
GREEN DENSITY - g./ml.
SINTERED AT 880°C.
R.C.S.
○ 1% ZINC STEARATE
△ 0·5% ZINC STEARATE
▽ 0·5% LITHIUM STEARATE
WITH −100 MESH POWDER No.1
● 1% ZINC STEARATE
▲ 0·5% ZINC STEARATE
▼ 0·5% LITHIUM STEARATE
WITH −200 MESH POWDER No.1

Fig. 4.—Green radial crushing strength and sintered density as functions of green density and lubricant. (Powder No. 1).

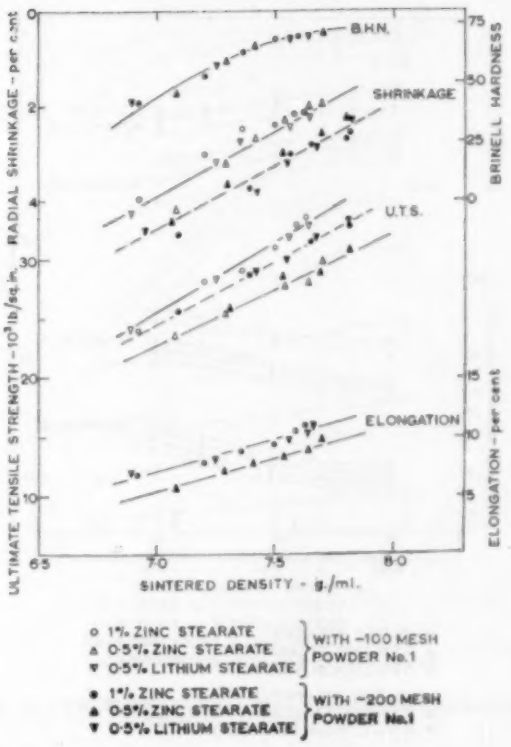


Fig. 5.—The effect of sintered density on mechanical properties of nickel brass 60/10/30 (Powder No. 1) compacts sintered at 880° C.

in Table I. The variation in average particle size of powder and the lubrication qualities of $\frac{1}{2}$% and 1% zinc stearate and $\frac{1}{2}$% lithium stearate were determined by blending these materials with −100 mesh and −200 mesh grades of powder.

Compacting Pressure

The densities of green and sintered compacts are shown as functions of compacting pressure in Fig. 2. For all conditions, an increase in pressure causes a rapid increase in green density, which is then followed by a reduced rate of densification. This hyperbolic relationship indicates an optimum practical moulding pressure of between 30 and 35 tons/sq. in., above which the work-hardening of the powder grains and the increased die wall friction necessitate large increases of pressure for small increases in density. The optimum moulding pressure is also illustrated with respect to the sintered compact in the upper curve of Fig. 2, but the effect of pressure is modified by the greater shrinkage which results from compacts produced at lower pressures, and exercises considerable control on the final density.

For a given compacting pressure, slight increases in green density were obtained with compacts of smaller average particle size, and the maximum green density with 1% zinc stearate lubrication. These improved pressing characteristics, however, did not lead to improved properties on sintering.

The influence of compacting pressure on mechanical properties of specimens sintered at 880° C. is shown in Fig. 3, from which can be seen that all properties increase with increasing pressure. It will be noted that there is no significant change in tensile strength in compacts containing $\frac{1}{2}$% zinc stearate and $\frac{1}{2}$% lithium stearate, but a substantial reduction in this property is found with 1% zinc stearate additions. It is considered that this is due to inadequate sintering caused by incomplete volatilisation of the lubricant, a state of affairs which would be accentuated by increasing compacting pressures. Ductility as measured by elongation, increases linearly with pressure over the range studied, whilst hardness tends to a constant value for pressures greater than 30 tons/sq. in.

Density

It can be seen from Fig. 4 that the green strength of compacts increases rapidly with rise in green density. There is no significant difference arising from the different lubrication treatments of the finer grade powders, and the −100 mesh powder with 1% zinc stearate. Improved green strengths are obtained as the amount of lubricant is decreased.

Fig. 4 also shows the linear relationship between green and sintered densities, and indicates the greater degree of consolidation associated with the larger shrinkage of the −200 mesh powders. The importance of sintered density in obtaining maximum mechanical

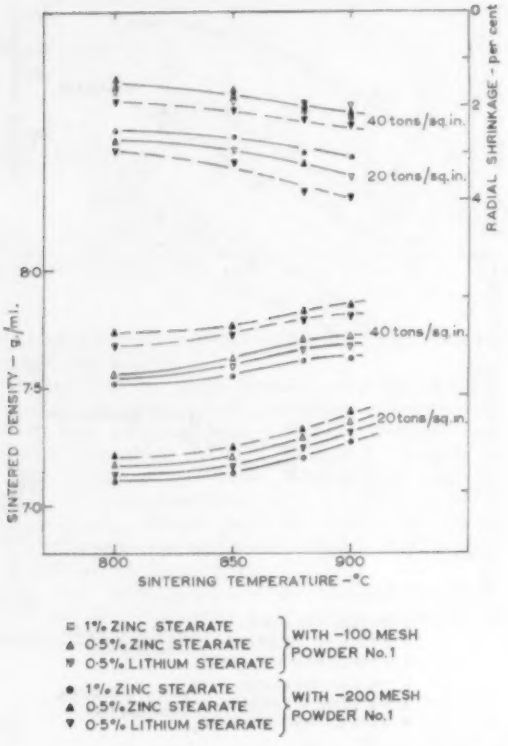


Fig. 6.—The effect of sintering temperature on sintered density and radial shrinkage of 60/10/30 nickel brass (Powder No. 1) pressed at 20 tons/sq. in. and 40 tons/sq. in.

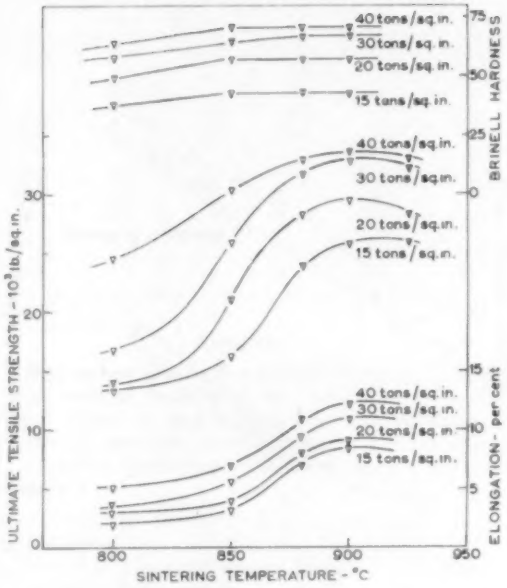


Fig. 7.—The effect of sintering temperature on mechanical properties of 60/10/30 nickel brass (Powder No. 1) lubricated with ½% lithium stearate.

properties is illustrated in Fig. 5. The variation of hardness with density appears to be insensitive to particle size and lubricant. Both tensile strength and ductility show a linear relationship up to 90% solidity, with maximum strengths obtained from ½% lubricant additions. The incomplete sintering in the case of 1% zinc stearate lubrication is also apparent.

Sintering Temperatures

It is well known that the time and temperature of sintering are complementary factors, i.e., cohesive strength of the compact increases with prolonged time at a given temperature and with increasing temperature for constant time. For this investigation, however, sintering times were maintained constant at 30 minutes to approximate to conditions suitable for production-scale operation, and the effect of temperature variation over the range 800 to 930° C. was studied.

The effect of sintering temperature on the density of specimens compacted at 20 and 40 tons/sq. in. is shown in Fig. 6. At the lower pressures a continuous rise in density is found for increase in temperature, whilst compacts pressed at 40 tons/sq. in. show a slow rate of increase to a maximum at approx. 900° C. The importance of shrinkage in controlling the rate of change of density with temperature is also shown in Fig. 6.

Fig. 7 shows an increase of both tensile strength and elongation with rising temperature at various compacting pressures, and shows maximum values for both these properties at approx. 900° C. Hardness figures were in general unaffected by change in temperature over the range studied.

On the basis of these results it is noted that

(*a*) Higher properties are obtainable from compacts lubricated with ½% lithium or zinc stearate, compared with a 1% zinc stearate addition. Whilst the results do not show any significant differences between the two stearates, the following observations, made during processing, suggest the lithium treatment is preferable:

(*i*) a more homogeneous mixture of lubricant and powder is obtained with lithium stearate;

(*ii*) to overcome agglomeration of zinc stearate, blending at 60° C. was required; no agglomeration occurred with lithium stearate at room temperature;

(*iii*) higher pressures were required to eject zinc-stearate-lubricated specimens from the die.

(*b*) The marginal increase in properties obtained from the —200 mesh grades of powder is insufficient to compensate for the higher cost of these materials.

(*c*) The optimum pressure is between 30 and 35 tons/sq. in.

(*d*) The optimum sintering temperature is between 880° and 900° C.

II.—Composition Variables

The influence of variations in copper content and of lead, iron and phosphorus are considered in this section. It was found that the effects of temperature and lubricant follow the trends outlined above: all compacts have

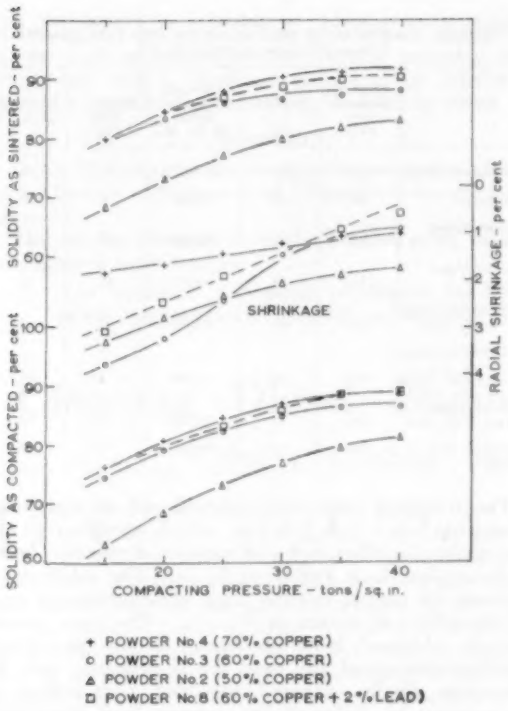

SOLIDITY AS SINTERED - per cent
SOLIDITY AS COMPACTED - per cent
RADIAL SHRINKAGE - per cent
SHRINKAGE
COMPACTING PRESSURE - tons / sq. in.
+ POWDER No.4 (70% COPPER)
○ POWDER No.3 (60% COPPER)
△ POWDER No.2 (50% COPPER)
□ POWDER No.8 (60% COPPER + 2% LEAD)

Fig. 8.—Solidities and shrinkage of compacts with varying copper and lead contents.

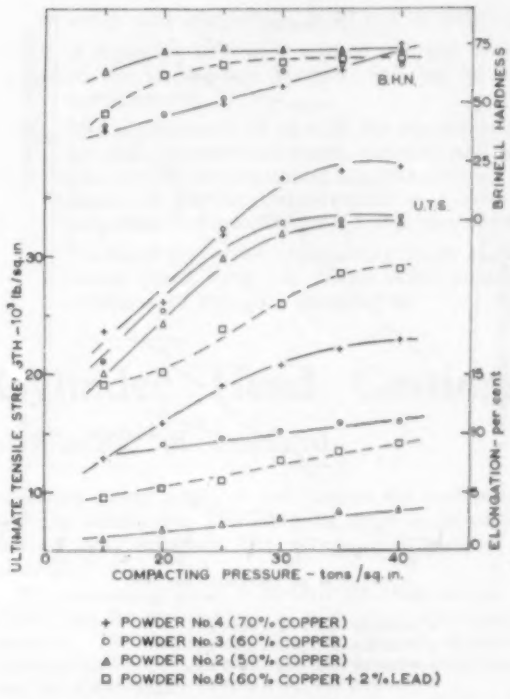

ULTIMATE TENSILE STRE, 3TH - 10³ lb./sq.in
BRINELL HARDNESS
ELONGATION - per cent
B.H.N.
U.T.S.
COMPACTING PRESSURE - tons / sq. in.
+ POWDER No.4 (70% COPPER)
○ POWDER No.3 (60% COPPER)
△ POWDER No.2 (50% COPPER)
□ POWDER No.8 (60% COPPER + 2% LEAD)

Fig. 9.—The effect of compacting pressure on mechanical properties.

therefore been lubricated with ½% lithium stearate and sintered at the optimum temperature to produce maximum properties.

Copper and Lead

The effect of copper was studied through alloy powders 2, 3, and 4, containing nominally 50%, 60% and 70% copper respectively, together with 10% nickel. Powders 3 and 4 form a homogeneous solid solution at all temperatures, whilst powder 2 has a two-phase structure. In view of the differences in the specific gravities of these materials, all green and sintered densities are expressed as percentages of the theoretical value, for purposes of comparison.

Figs. 8 and 9 show the effect of compacting pressure on green and sintered properties. Over the range of pressure studied, the greatest tensile strengths are obtained from the single-phase (60% and 70% copper) alloys. This condition might appear directly opposed to the properties expected from wrought alloys of similar compositions. However, Fig. 8 shows that the two-phase powder has a greater inherent hardness, since compacts pressed at 40 tons/sq. in. show only 80% solidity, compared with 90% for the solid-solution alloy powders. This is also further illustrated in Fig. 10, where the mechanical properties are considered as a function of sintered solidity. For comparable degrees of solidity, the strength of the two-phase alloy shows an increase of approximately 10,000 lb./sq. in., compared with that of the single-phase compact. The other properties behave quite normally, ductility increasing rapidly with increasing copper content, whilst hardness shows the reverse trend.

The effect of adding 2% lead to a basic 60/10/30 composition is also considered in Figs. 8 and 9, which show improved pressing characteristics in the form of higher green solidities. The low solubility of lead in this alloy causes the formation of a liquid phase and higher sintered densities, but the isolated nature of the lead phase reduces the strength and ductility of the compact.

Iron and Phosphorus

The torsional properties required from materials used in the manufacture of key blanks prompted the making of pre-alloyed additions of iron and phosphorus to a basic 60% copper–10% nickel–30% zinc composition—powders 5, 6 and 7.

Effects of compacting pressure and sintering temperature during the processing of these powders were similar to those reported in Section I, but the presence of phosphorus enabled sintering to be carried out at lower temperatures. Comparing the properties with those of compacts containing no additions, it was found that iron caused an increase in green and sintered densities, whilst the work-hardening effect of iron and phosphorus together resulted in a decrease in both these properties. The influence of compacting pressure on the mechanical properties of specimens sintered under optimum conditions is shown in Fig. 11, from which it can be seen that the presence of iron gave increased strength, ductility and hardness compared with the standard alloy, whilst the combined iron and phosphorus additions caused maximum increase in tensile strength and hardness at the expense of ductility.

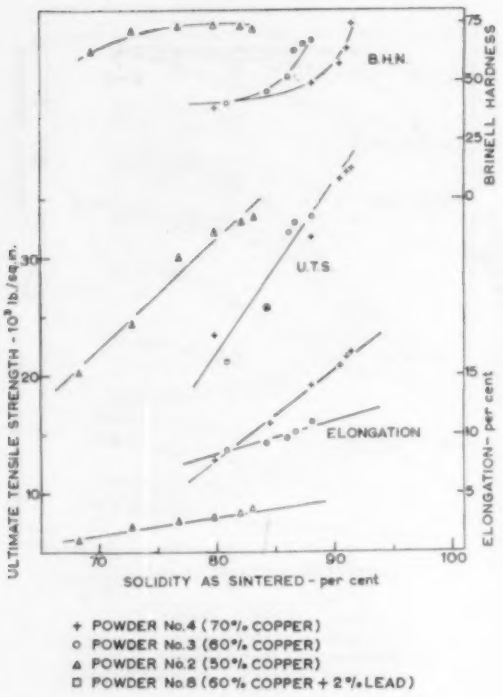

B.H.N.
U.T.S.
ELONGATION
ULTIMATE TENSILE STRENGTH - 10³ lb./sq.in.
BRINELL HARDNESS
ELONGATION - per cent
SOLIDITY AS SINTERED - per cent
+ POWDER No.4 (70% COPPER)
o POWDER No.3 (60% COPPER)
△ POWDER No.2 (50% COPPER)
□ POWDER No.8 (60% COPPER + 2% LEAD)

Fig. 10.—The effect of solidity on mechanical properties.

TABLE II.—COMPARISON OF MECHANICAL PROPERTIES OF NICKEL BRASSES WITH LEADED BRASS AND 70/30 BRASS
(Compacting Pressure 30 tons/sq. in.)

Material	Sintering Temperature (°C.)	Solidity (%)	Ultimate Tensile Stress (lb./sq. in.)	Elongation (%)	Hardness (B.H.N.)
80/20 Leaded Brass	880	90	28,000	20	48
70/30 Brass	880	88	28,000	8	50
70/10/20 Nickel Brass	940	90	36,000	16	57
60/10/30 Nickel Brass	880	88	33,000	10	65
60/10/30 Nickel Brass + 1·5% Iron	880	89	35,000	12	68
60/10/30 Nickel Brass + 1·5% Iron + 0·5% Phosphorus	850	86	36,000	8	75
60/10/30 Nickel Brass + 2% Lead	880	89	26,000	8	65
50/10/40 Nickel Brass	880	80	32,000	3	73

The torsional tests were carried out on specimens measuring $1{\cdot}7 \times 2{\cdot}5 \times 0{\cdot}1$ in., which were fixed at one end whilst the other end was capable of rotation under loads applied at a radius of $3\frac{1}{2}$ in. The relationship between the torque and the angle of deflection for each of the alloys is shown in Fig. 12. The poor results initially obtained from specimens in the as-sintered condition indicated the need for re-pressing, and the procedure finally adopted involved compacting at 35 tons/sq. in. followed by sintering and re-pressing at 35 tons/sq. in. It can be seen from Fig. 12 that the metal lattice is stiffened by the presence of iron, which increases the torque required for fracture and also the

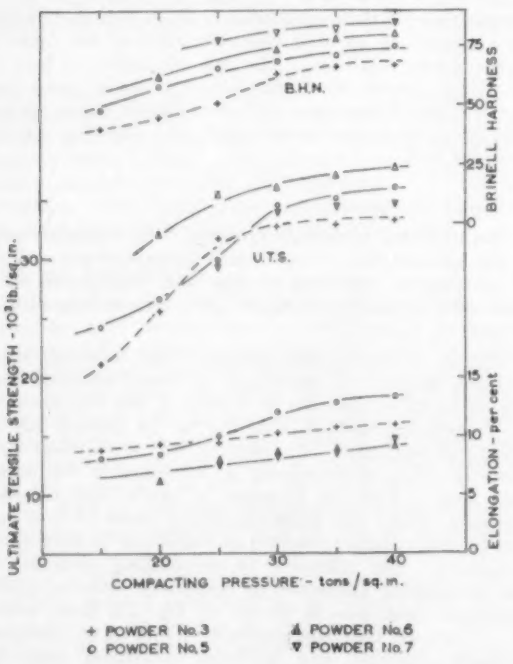


Fig. 11.—The effect of additions of iron and phosphorus on mechanical properties as functions of compacting pressure.

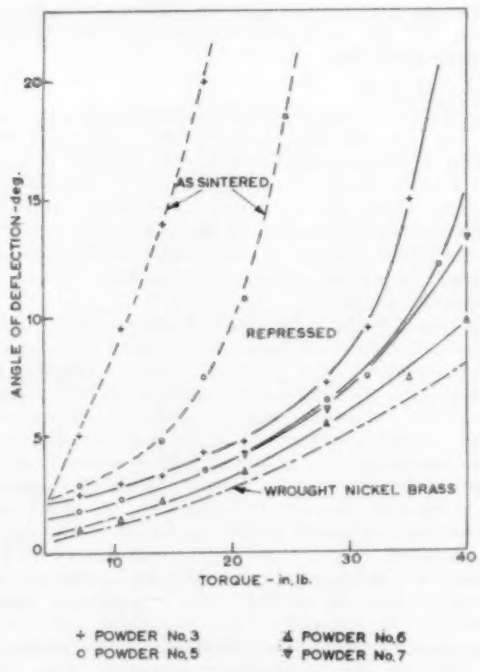


Fig. 12.—The effect of iron and phosphorus on the torsional properties of nickel brass.

resistance to deflection. The presence of phosphorus in the form of iron phosphide further increases these properties, and a condition only slightly inferior to that of a rolled nickel brass strip is obtained.

Summary

Table II compares the mechanical properties of 10% nickel brasses with those of 80/20 leaded brass and 70/30 brass.

The results obtained from the present work may be summarised as follows :—

(1) The optimum processing conditions for nickel brass components involve lithium stearate lubrication and compacting at 30 and 35 tons/sq. in.

(2) A reduction in copper content and the presence of the phosphorus permits sintering at lower temperatures.

(3) The replacement of part of the copper content by nickel improves strength, ductility and hardness, whilst the processing conditions remain the same. A further improvement in mechanical properties is obtained from a 1·5% iron addition.

(4) Torsional properties approaching those of rolled nickel brass strip are found with controlled additions of iron and phosphorus.

Cleaning Diesel Engine Cylinder Head Castings

Molten Caustic Bath Installation at Leyland

DIESEL engine cylinder head castings are now going through a supplementary cleaning process at the Farington Foundries of Leyland Motors, Ltd., which guarantees that all their intricate and largely inaccessible internal passages are completely free from traces of sand. In such castings, even with the first-class application of modern coremaking techniques and special care in normal cleaning and shot-blasting, it has been difficult in the past to guarantee complete freedom from any residual sand. Leyland has now overcome this problem economically by building a production plant in which the castings are immersed in molten caustic soda. It has been designed by engineering departments of Leyland Motors Ltd., in close collaboration with Imperial Chemical Industries Ltd., and Thermic Equipment Co., Ltd., using data obtained from trials on a pilot plant at the I.C.I. alkali division, Northwich.

Because of the nature of the process, the plant is housed in a separate building adjoining the castings processing section. This simplifies the application of the necessary safety measures and ensures the best possible working conditions. The site is adjacent to the castings fettling bay, alongside the natural flow path of the castings.

A work basket containing cylinder head castings being withdrawn from the preheating furnace.

The processing plant is divided into four stages, the cycle time for the castings in each stage averaging 30 minutes. The stages are preheating, caustic immersion, draining and cooling, and finally washing in cold quench and hot rinse tanks.

Following shot-blasting and rough cleaning, the castings are loaded into a stout wire mesh basket and conveyed on a gravity roller conveyor into a preheating oven where they are heated for 25 minutes and reach a temperature of 130–150° C. The objects of preheating are to make certain that the castings are completely dry, to reduce the thermal shock in the caustic bath, and to relieve the thermal load on the caustic bath.

After preheating, the basket is picked up by one of two overhead monorail mounted hoists, taken through screen doors, and lowered into the molten caustic bath. This is constructed of welded 1 in. thick mild steel, holds 3½ tons of caustic soda, and is heated indirectly by gas burners. The castings remain in the bath for 25 minutes at a nominal 500° C., and are then removed and allowed to drain over the bath for 3 minutes.

Castings are drained for a further 20 minutes on an adjacent drain table, the hoist being disengaged to return and pick up the next basket. During this time the castings also cool down to approximately 250–280° C., which lessens the thermal shock in the next stage, the cold quench.

While there is a flow of water through the cold quench tank, the basket is lowered twice to rinse out the internal passages as thoroughly as possible. A feature of the tank is that it is deep enough for the basket to be lowered in and the top lid closed before the basket is lowered further for immersion.

After 10 minutes the basket and castings are transferred to a hot rinse tank where the washing is completed by a further 15 minutes immersion, the basket being raised and lowered again to rinse out the interiors. There is also a small flow of fresh water through the hot tank and the temperature is kept at 80° C., which is high enough for the castings to be self-drying after final removal from the tank.

A load of castings being lowered into the molten caustic bath. The screen door on the right is open only for the purpose of taking the photograph

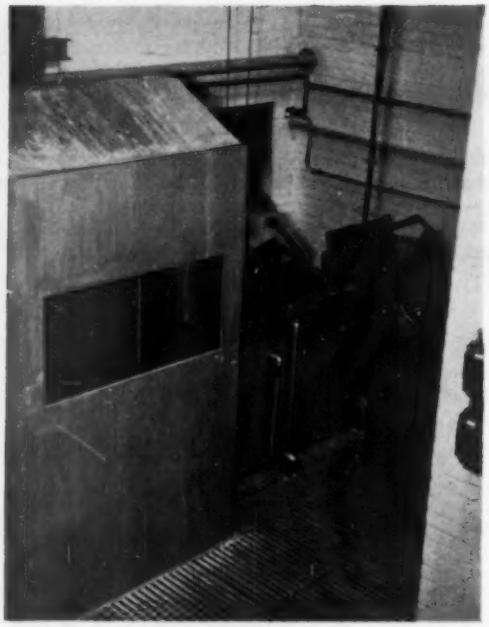
To facilitate sludge removal, two trays are inserted in the bottom of the caustic soda tank, and these are lifted out after each day's work carrying much of the sludge with them, the remainder being removed by a long handled scoop. With the type of work treated the loss of caustic due to drag out and sludge removal amounts to an average of 44 lb./ton processed. This is made up regularly by additions of flake caustic.

Special attention has been given to fume extraction to ensure very good working conditions, and powerful extractors are fitted over the caustic bath and cold quench tank. In addition, a curtain of fresh air is blown over the top of the caustic tank to provide better ventilation control.

The caustic tank, draining table, and cold quench tank are all completely screened off as a precaution against splashing, the operator manipulating the charges from outside the screen. Access and egress to and from the screened section for the basket is through double swing doors. The floor in the draining area inside the screen and the working area outside is covered by a metal grille to allow splashed liquids to drain away and also to facilitate easy cleaning. The floor drains away into a sump which also collects the overflow from the cold and rinse tanks. The effluent, after the sludge has been separated, is not strongly caustic and is accepted into the normal sewage system.

In designing the plant every possible precaution has been taken to reduce to the minimum the inevitable hazards which exist when dealing with this material. The operator always wears goggles and a protective helmet against the unusual event of splashes coming out of the screened area. For entry into this area for de-sludging and other tasks, special protective clothing and a helmet with a hood are worn.

As a further precaution, buffered phosphate solution is readily available in the plant in eye wash bottles for immediate use, and as a bulk supply to flood any affected part of the person. Operators have been shown how to give first aid on the spot in the unlikely event of a mishap, and instructed in the need for observing reasonable precautions and avoiding over-familiarity with the caustic material. Printed warning notices on the plant serve as a constant reminder.



After washing in the cold quench tank behind the screen on the left, the castings are given a final hot water wash in the tank on the right.

Shelton Kaldo Plant from Davy-Ashmore

DAVY AND UNITED ENGINEERING CO., LTD., a member of the Davy-Ashmore group, has received an order from Shelton Iron & Steel, Ltd., for the design, supply and installation of oxygen-blown Kaldo furnace plant at their Etruria Works, Stoke-on-Trent. The contract is valued at approximately £1 million. Davy-United will also be responsible for the overall engineering of the whole of this project, which will comprise the first complete steel melting shop in the United Kingdom to use only Kaldo furnaces. These furnaces will have a capacity of 55 tons of liquid steel at each charge. As these furnaces will be of wholly British design and manufacture, this order marks an important step forward in the field of British plant supply for oxygen steel making processes. The engineering, layout and design of the plant will be undertaken by the steel processes division of Davy and United Engineering Co., Ltd., and a substantial proportion of the contract will be manufactured at Stockton.

Bauxite in Sierra Leone

MINING of bauxite is likely to begin in the Mokanji Hills in Sierra Leone's South-Western Province early next year, states Barclays Bank D.C.O., in a report from Freetown. The Government's Geological Department has carried out extensive prospecting in that area on behalf of the Swiss Aluminium Co. of Zurich. During the course of the prospecting 250 drill holes were sunk and the mineral occurs in a narrow band over a length of about 18 miles; the thickness of the deposit varies up to a maximum of about 70 ft., and averages about 30 ft.

Copper and Copper Alloys

A Survey of Technical Progress During 1960

Compiled by the Staff of the Copper Development Association

This survey is a summary of current developments in the field of copper and copper alloys over the past year. Aspects covered include extraction, fabrication, finishing, properties and testing. Review articles are, in general, excluded.

(*Continued from page 136 of the March issue*)

Electrical Properties and Applications

Printed Circuits

Copper-foil printed circuits continue to be the subject of extensive research and development, and their design and production are comprehensively discussed, for example, by Dyer and Solaro,[62] whilst another paper deals specifically with limited quantity production.[63] Improvements relating to circuit manufacture include the Phillips transfer process,[64] whereby waste of copper is minimised by producing the circuit on a separate carrier which is later transferred to the plastic, and the development of the flush printed circuit described by Chellis,[65] in which the circuit is inset in the plastic. A further method of producing flush circuits is the " printed pattern " process patented by Malcolm,[66] in which the inset circuit is cut directly out of sheet foil by compressing the foil between engraved insulation and a sheet of rubber.

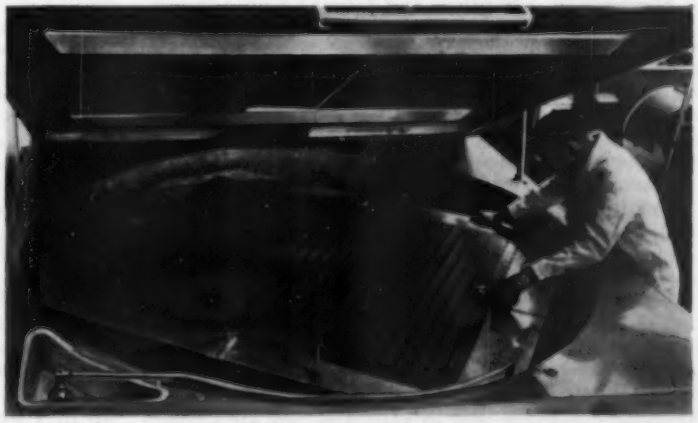
Printed circuits produced on ceramic material in order to operate at high temperatures can now be made by a process which dispenses with the use of adhesives for bonding. Developed by the Bell Telephone Laboratories, this method utilises the ceramic firing process to form the printed circuit from a copper-bearing paste, produced in the required pattern by means of standard silk-screening techniques.[67]

Materials for High Temperatures

Other developments in connection with high-temperature insulation are those of firing porcelain enamels on to copper and platinum sheet, and of producing magnet wire with a flexible ceramic insulation. Bergeron, Schwarzloss and Friedberg[68] have determined the dielectric constant, dissipation factor, and resistivity of clear-base and copper-oxide-containing porcelain enamel coatings on metal sheet for 0·1–100 kc./s. at room temperature and at temperatures up to 700° F. (370° C.), whilst these authors also investigated the effects of firing temperature and coating thickness.

Ceramic insulation for magnet wire has been tested on nickel-clad copper[69] and is reported to be capable of operating continuously at 1,000° F. (540° C.) and to have a maximum safe operating temperature of 1,500° F. (815° C.). Some conductor materials for magnet wire, discussed in an investigation by Jarvitz[70] on the effect of nuclear irradiation and temperatures up to 600° C. (1,100° F.), include copper-aluminium, copper-nickel, copper-manganese and binary alloys of the copper-zinc system. Estimates for the thermal life of magnet wire have been found for a wide range of insulating materials,[71] whilst the thermal ageing of insulation under the effect of gamma irradiation has been studied by Kallander.[72] Such properties are important in the nuclear-energy field, and for aircraft electrical power equipment operating at high temperatures. The latter environment is discussed by McKenzie,[73] whilst Sideris[74] details many special properties required in electronic materials used in high-speed flight.

The aircraft industry also provides an application for the recently-developed copper-zirconium alloys which, by reason of their superior high-temperature properties, are replacing other commutator materials in electrical machines of high power-to-weight ratio; the range of alloys, containing from 0·01 to 0·15% zirconium, have been described in detail[75, 76] and at least two patents relate to them.[77, 78]



Courtesy of Printed Circuits, Ltd.

A large area of copper printed circuits, 1,000 of which are printed on one board.

Electrical Machines

New designs for high-speed commutators with and without gas cooling have been patented by Clarke and Preston and others.[79-80] It is claimed that these designs provide locking and tensioning forces which tend to oppose the bursting force of centrifugal effect and at the same time provide a greater degree of stiffness. In the U.S.A., a new gas-cooling technique has been used for the stator windings of steam-turbine generators.[81] The copper coil strands in the stator are transposed around a total of 6,000 ft. of rectangular stainless-steel tubing through which hydrogen gas passes at velocities up to 10,000 ft./min., transferring heat from the stator coils and keeping them at permissible temperatures.

Cooled hollow copper conductors for electrical equipment were discussed by Cogle, Hartill and Tudge in one of four papers presented at a C.D.A. Symposium[82] devoted to the use of copper in various branches of electrical engineering. At the same meeting,[82] Gee reviewed the use of copper in power transformers, Hall and Meggs described the design and manufacture of copper waveguides, and Richards dealt with the range of copper alloys available for conductivity applications.

Other Electrical Components

Electronic memory devices have been developed which employ fine copper wire wrapped with magnetic alloy tape.[83-84] Such memories can supply information to a computer in millionths of a second and are said to be comparatively inexpensive and easy to produce. Two researches on contactor materials are Baxter's investigation[85] into contactor performance, which includes the behaviour of copper and copper alloy contacts, and an investigation by Naidenow and Hoffrichter[86] on the erosion resistance of contact materials in low-voltage oil-immersed switchgear.

The interconnections between electronic components, printed circuits, etc., can now be carried out using flexible cable, which consists of a flat insulating ribbon containing a number of copper-foil conductors.[87] Angele[88] has investigated the characteristics of a number of flat flexible cables and has compared their load-carrying capacities with conventional cables.

Mechanical, Chemical and Marine Engineering

Heat Transfer and Chemical Plant

In the field of heat transfer, Eshaya and Dodge[89] have described the operation of a sea-water demineralisation plant where satisfactory promotion of dropwise condensation on the heat-exchanger surfaces would result in considerably reduced operating costs. However, while satisfactory dropwise condensation has been maintained for periods of time in the region of 3,500 hours, the problem of how to maintain the film of promoter for considerably longer periods will have to be solved before the scheme can be considered as an economical proposition in industry. So far, promoters containing either sulphur or selenium have shown great promise when used on copper and copper-base alloys. A useful study is being made at the Warren Spring Laboratory of the D.S.I.R.,[90] where the manner in which certain promoters function, and in particular, the mechanisms whereby they are attached to the metal surface, are being investigated. Certain hydrophobic organic compounds containing sulphur are the subject of this study, the prime object of which is to develop compounds having a more permanent effect on the condensing surface.

Melichar,[91] in considering the design and operation of sieve trays for distillation columns, has commented upon recent developments in a new type of tray perforation. In addition to giving a tray of increased rigidity, a further advantage of this type of perforation is that it gives rise to radial flow of the liquid, a much-desired characteristic in this type of plant. The trays described, normally made of either copper or brass, are to be used for the separation of liquefied gases at low temperatures.

A useful contribution to the rupture characteristics of safety diaphragms (bursting discs) has been made by Weil,[92] who investigated the instability criteria for materials obeying a parabolic stress-strain law. He describes a method whereby bursting pressures may be predicted, and gives data for annealed and hard-temper copper to support the theories and experiments carried out.

Spark Machining

The use of spark machining for the production of intricate dies and cavities in hard metals is becoming increasingly popular. Schultz[93] has described how electrodes may be made by spraying copper into moulds of appropriate form, using a release agent to prevent adhesion. Sprayed electrodes, in which metal up to ¼ in. thick is sometimes deposited, are claimed to have a very high degree of dimensional accuracy. Ullmann[94] outlines five methods by which large copper electrodes are produced; coining and cold hobbing are two of the most frequently used methods, whilst both metal spraying and sand casting each have their own particular virtues for certain applications. Electrodes of pure copper may be prepared by the technique of electroplating a plastic shell of the required form. In addition to electrodes made of copper, Adcock[95] describes the use of brass, copper-tungsten, and copper-graphite mixtures, outlining the respective merits of each material.

Metal Cutting

A critical comparison of metal-cutting theories with new experimental data has been made by Kobayashi[96] and others. Orthogonal metal-cutting tests at various cutting speeds, rake angles and feed rates were undertaken to gain additional understanding of the effect of cutting speed and metallurgical structure on shear strength in metal cutting; attempts were made to correlate shear properties in metal cutting with those obtained from static tests. Some interesting information came to light at the works of Alvis Ltd.,[97] where a detailed cost analysis has shown that substantial economies have been effected by the use of ceramic tools in place of tungsten-carbide tools for machining gunmetal mounting rings and oil-retaining gunmetal sleeves.

Friction and Wear

The sliding characteristics of metals at elevated temperatures have been determined by Peterson, Florek and Lee[98]; friction tests were carried out on copper and other metals, each in contact with itself, at temperatures up to 1,500° F. (815° C.). In each case, a transition temperature was observed, below which considerable damage was caused by friction. Above the transition temperature, however, the sliding characteristics showed considerable improvement. This is attributed to the

formation of metal oxides in the sliding track, which effectively reduce the friction, thus preventing excessive damage. Investigations into the microstructure of sand-cast leaded tin-bronze gears,[99] revealed that wear resistance was increased by slow cooling of the casting; one recommendation made is that the castings should be heated for twenty-four hours at 930° F. (500° C.), followed by water quenching, in order to homogenise the structure.

Corrosion

Without a doubt the most outstanding contribution to corrosion literature during 1960 was U. R. Evans' book[100] on corrosion and oxidation, which includes much of interest relating to copper and its alloys. Essentially, it presents the author's views gained from his intimate association with the subject over many years, and incorporates an impressive list of additional references, thus resulting in a comprehensive and authoritative book on every aspect of corrosion theory and practice.

Stress Corrosion

One can visualise an increase in the popularity of the high-tensile beta brasses, if Bailey's claim[101] that about 2% nickel or cobalt significantly reduces their susceptibility to stress corrosion is fully substantiated in practice. In examining the effect of composition on the intercrystalline cracking of cast beta brass, the same author shows, however, that cobalt encourages dezincification;[102] nickel on the other hand, in the presence of iron, overcomes cracking difficulties without any such side effect. Following the premature failure of some annealed Admiralty-brass condenser tubes, Nelson[103] concluded that roll straightening had induced sufficient internal stresses to cause stress-corrosion cracking during service.

Mercury-Bearing Alloys

Much interest has been aroused by Bulow's[104] patents covering the addition of 0·001–1% mercury as an alloying element to copper, brass, and other copper-base alloys. Apart from increasing their corrosion resistance, the materials are said to have superior resistance to bio-fouling, impingement and, in the case of the brasses, dezincification. Confirmation of these claims in practice will be awaited with interest.

Corrosion-Resistant Applications

In reviewing materials used in the petroleum industry, Swales[105] considers the aluminium bronzes to be particularly useful, due to their combined high strength and corrosion resistance; for applications where erosion is important, he states that the complex alloys are preferable. The effect of various operating conditions in neutral and alkaline brine evaporators was investigated by Turnbull,[106] who found copper alloys particularly useful due to their resistance to crevice attack. For heating corrosive liquids, such as pickling or plating baths, lead-clad copper tubing as discussed by Thomas[107] would seem to be admirable, since it combines the corrosion resistance and thermal conductivity of copper with the acid resistance of lead.

Inhibitors

The addition of sodium benzoate and nitrite to ethylene glycol solution was shown by Mercer and Brasher[108] completely to inhibit corrosion of copper, and also to prevent copper deposition on steel in the same system. Similar results were obtained by Cessna,[109] —who also found borax beneficial—and Mercer and Wormwell,[110] while benzotriazole,[111] as an inhibitor to overcome steel corrosion in systems containing copper is the subject of a further patent. Vapour-phase inhibitors have proved useful for some metals but not, as yet, for copper, as pointed out by Sexton,[112] who reports discoloration and even pitting consequent to their use. A fortuitous case of inhibition in food-manufacturing equipment is quoted by Moss;[113] in spite of the presence of ammonia, copper parts are apparently protected by glucose and other sugars.

Courtesy of International Nickel Company of Canada, Ltd.

This oxygen vaporiser for a Canadian oxygen plant weighs 10 tons and contains 25,000 ft. of copper tube.

Oxide and Sulphide Films

The growth of oxide films on copper immersed in water was investigated by Kruger,[114] who found that with a *p*H <5·7 cuprous oxide formed, whereas at *p*H 7 both cuprous and cupric oxides were stable, the latter changing to cuprous oxide if the *p*H were subsequently lowered. Miller and Lawless[115] also carried out similar work with aerated copper sulphide solution. Colour photo-micrography has been employed by Stockbridge[116] to follow the growth of sulphide films on copper.

General

Cavitation-erosion tests carried out by Matthieson and Hobbs[117] indicate that the time lapse before cavitation damage initially occurs is directly related to the fatigue strength of the material. Of the alloys tested, aluminium bronze gave the best results. The corrosion of copper and its alloys embedded in soil has been shown to be due to electrolytic action, and to depend essentially on the *p*H and water content of the soil.[118] Some interesting results from galvanic corrosion tests in cellulose wash liquors containing sulphur dioxide, typical of the paper

industry, are presented by Uusitalo,[119] who found that when copper alloys and stainless steel are in contact, the anodic member is determined by the degree of aeration of the solution.

Finishing and Plating

Cleaning

A new, economical method for bulk cleaning of nickel silver spoons and forks in the catering industry has been recommended[120]; the flatware is treated in a mixed solution of tetra-sodium ethylene diamine tetra-acetate and penta-sodium diethylene triamine penta-acetate with a non-ionic synthetic detergent. To obviate subsequent staining of the nickel silver by air, moisture or heat, sodium perborate and sodium metasilicate are added to the solution after the cleaning process but prior to rinsing. Another interesting cleaning solution[121] for copper-base materials consists essentially of an aqueous solution of an alkali metal polyphosphate detergent to which is added a water-soluble stannous salt; this is claimed to lessen the tarnishing action of the polyphosphate.

Popular for some time in America and recently introduced to the British market are rapid cleaning agents with a powerful ability to remove sulphide and oxide discoloration from copper; one such cleaner[122] consists of a mixture of weak acid, abrasive, thiocarbamide and viscous alcohol. A typical use for these cleaning materials is for quickly and easily refurbishing copper kitchen utensils after long service on a gas cooker.

For cleaning copper prior to electroplating, a 25% solution of ammonium persulphate has been recommended[123]; it is claimed that immersion of copper in this solution for 10 to 60 seconds at room temperature provides an oxide-free surface, which is particularly suitable for the production of a low-porosity electrodeposit.

Polishing

Both chemical and electrolytic polishing of copper-base materials continue to increase in popularity, and the merits of each process, the equipment required, and the results obtained have been assessed by Wells.[124] Recent trends in this field have been discussed by Pinner,[125] who reports on the application of these procedures to, for example, thinning of copper and cupro-nickel foils and polishing the internal surfaces of waveguides. The eminent suitability of electrolytic polishing for brass, nickel silver, gilding metal and copper articles of controlled grain size has been emphasised by Zentler-Gordon and Boyle,[126] who instance its expanding use for various applications of these metals.

Electrodeposition of Copper

Oxygen-free high-conductivity copper anodes containing 0·0001 % lithium are claimed by Von Tillburg[127] to effect more uniform solution, minimise anode sludge and provide a cathode deposit free from nodular growth. Research on the ever-popular copper sulphate bath has included a study of the growth habit of the deposits, at both polycrystalline and single crystal cathodes,[128] and an investigation of the levelling power obtainable with various addition agents.[129] Aiken and Howard[130] claim that copper and copper alloys can be deposited from a solution in which hydroxy-cyclohexyl-ethylenediamine-triacetic acid is used as the sole complexing agent and suggest that such a formulation could supersede cyanide baths. They point to the disadvantages of the latter, namely their toxicity, the difficulty of disposing of them, and their tendency to decompose by oxidation or hydrolysis.

Canadian research has shown that copper can be electroplated directly on to aluminium and aluminium alloys from an appropriate highly acidic solution of *p*H 4 or less[131]; also from a bath of *p*H 5·0–6·5 containing bivalent copper, pyrophosphate and/or polyphosphate, oxalate or malonate as well as ammonia and/or tertiary amine.[132] From Germany and Russia comes the information that copper can also be plated directly on to iron and steel using an acid sulphate bath; this is said to be successfully accomplished either by using an appropriate prior pickling treatment[133] or by additions of tribenzylamine and thiourea to the plating bath.[134] An appropriate cleaning and plating schedule for "coppering" stainless steel wire has also been described,[135] the purpose of the copper being to serve as a lubricant during drawing.

Electrodeposition of Copper Alloys

Progress in the electrodeposition of brass has been discussed by Ehrlich,[136] who concludes that "radical improvements must await the development of better complexing agents and more stable brighteners." Sree and Rama Char[137] found that pyrophosphate baths possess some advantages over cyanide baths for brass plating, while Cole and O'Neill[138] studied the transformations which take place in electrodeposited brass. They suggest that metastable ductile brass coatings might be applied to metal sheets to be deep pressed so that, after pressing, the coatings could transform to harder structures more resistant to scratching.

The durability of tin bronze and copper undercoats beneath nickel and chromium has been assessed by Lowenheim and Rowan,[139] while working experience in the use of bronze, copper and other deposits as "masks" in the nitriding and carburising of steels has been reported by Modjeska and Gary.[140]

Electroplating on Copper and Copper Alloys

The opinion is sometimes expressed that cadmium coatings electrodeposited on to copper and copper alloys can lead to a marked reduction in the ductility of these materials by inward diffusion of the cadmium at room temperature; Boxall and Hallowes[141] have shown this to be untrue.

The application of a tin-nickel alloy coating to copper, brass and steel parts is now a popular finishing process in the watch and clock industry, to combat corrosion and to reduce friction on moving parts.[142] Another alloy electrodeposit, 20% cobalt-nickel, is used in an automatic plant for plating of brass razor components.[143] In the tin-plated-copper-wire industry, it has been shown that production can be increased by drawing the wire at 1,500 ft./min. through a stannous sulphate bath, using forced circulation.[144]

Electroforming

The production of copper and copper-nickel bi-metal sheets, by electrodeposition, has been described by Carrington,[145] who gives operational data and process control for the acid copper sulphate and nickel sulphate/boric acid/potassium chloride baths used; a claimed improvement[146] in the apparatus employed for such

copper sheet electrotorming is to feed the electrolyte through a tubular discharge manifold so that it flows along the surface of the rotating drum cathode.

Andrews[147] has described the electroforming of copper waveguides from an acid sulphate bath, giving electrolyte composition and temperature, rate of deposition, bath maintenance, type of mandrels required and cleaning and plating instructions. Problems arising in the manufacture of electroformed components and means of overcoming them have been discussed by Spiro.[148]

Non-Electrolytic Deposition of Copper

A comprehensive paper by Saubestre[149] deals with the principles of "electroless" copper plating and some of its past history, and assesses the merits of various solution compositions for the production of thin and thick non-electrolytic copper deposits.

Joining

As a result of work carried out at the British Welding Research Association, Young and Clews[150,151] have reported that sound, porosity-free joints in zinc-deoxidised copper (0·5–3·0% Zn) can be made by autogenous argon-arc welding. Both the thermal and electrical conductivities of this material are high, and light-gauge sheet can be satisfactorily welded without the use of a separate filler rod. This suggests that zinc-deoxidised copper could be advantageously employed for the fabrication of back boilers, water heaters, heat exchangers, hot- and cold-water storage tanks, and other applications where high conductivity and good corrosion resistance are essential.

An economical method of producing copper and copper alloy tubes by high-frequency resistance welding has been developed by the New Rochelle Thermatool Corporation.[152,153] In this process, the tube is formed from light-gauge strip and the abutting edges welded longitudinally at rates varying from about 100 ft./min. in the case of copper, to more than 250 ft./min. for brass. The principal outlet for such tube, which is available commercially in Gt. Britain, appears to be for certain engineering, heat transfer, and cable sheathing applications. A recent development in the field of heat-exchanger fabrication is an automatic tube-welding gun,[154] which utilises the inert-gas-shielded tungsten-arc welding process. The gun, designed primarily for non-ferrous alloys, has been used for the welding of tubes to tube-sheets in surface condensers.

Ultrasonic welding of dissimilar metal combinations, which are difficult or impracticable to join by conventional methods, is now being performed successfully.[155,156] Joints, which have been found to be free from intermetallic compounds and brittleness sometimes associated with fusion bonding, have been made between copper or brass and aluminium, steel, nickel, gold, platinum and zirconium. In studying ultrasonic welding, Weare, Antonevich and Monroe[157] have investigated the mechanism of bonding and the effects of welding variables on joint quality in different materials. In the case of copper, weld-zone temperatures were measured and the relationship between breaking load and welding time of copper-Monel joints was determined.

The significance of surface preparation in roll bonding has been considered by Vaidyanath and Milner;[158] the bond strength characteristics of copper and aluminium were determined after various types of surface preparation, and highest bond strengths were obtained with scratch-brushed surfaces. Interesting experiments have been made on the welding of dissimilar materials by means of explosive pressures;[159] shear strengths as high as 17,000 lb./sq. in. have been obtained in joints between brass and stainless steel. Also concerned with the joining of dissimilar metals, Tesmen[160] has outlined some Russian experiments which show that copper, brass and bronze are among the metals which can be welded to themselves, or in dissimilar pairs, by the process of friction welding. Bartle and Young,[161] while experimenting with the use of high-frequency induction brazing in argon streams, for joining copper to titanium sheet, found that the most satisfactory filler materials were silver-copper-palladium and silver-copper eutectics.

Powder Metallurgy

Preparation of Powders

An American concern has reported a new powder atomisation technique said to produce exceptionally clean, fine, specifically-shaped pure or alloy metal powders; copper, nickel silver, copper-nickel-cobalt, chromium copper and copper-nickel-tin are among the metals suitable for the process.[162] Another American firm is making spherical copper powders, with uniform particle sizes from 20 to 150μ, in an inert atmosphere; the powders are said to be free from voids or inclusions, and size uniformity is claimed to be 98%. Typical products from these powders include filters, sweat-cooled nozzles, and other sintered articles requiring controlled porosity.[163]

Compacted and Sintered Components

Three copper alloy parts have won awards for the best application of non-ferrous powder metallurgy in product design; they were a brass charge liner, a nickel silver ring for moulding into a plastics terminal block, and a nickel silver lever for a pneumatic controller. Each of these newly-designed powder metal parts resulted in lower production costs, closer tolerances, better surface finish and longer service life.[164]

Zaleski and Powell[165] have described an improved compacting technique for brass, using a lithium stearate lubricant, followed by sintering in nitrogen. These manufacturing conditions are said to increase the tensile strength of the products and to lower operating costs, while preliminary studies suggest that similar fabrication methods can also be applied successfully to copper compacts.

In the bearings field, Pound, Rowley and Elliott[166] have provided a comprehensive consideration of the factors influencing the economic fabrication of green bearing compacts on a volume production basis, devoting their attention to 90/10 copper-tin bronze as well as iron alloys containing up to 10% of copper. Recent developments in dry bearings[167] include sintered 89/11 copper-tin spherical-particle bronze powder with a steel backing. The pores of the compact are filled with a PTFE-lead mixture, which results in very low wear; the material is also available as thrust washers and as strip. Another new dry bearing[167] which is readily machinable, consists of PTFE, graphite and spherical bronze powder without a backing of steel.

Roll and Continuous Compacting of Powders

The Powder Metallurgy Group of the Iron and Steel

Institute and the Institute of Metals held a meeting on 12th April, 1960, to discuss continuous compacting processes for metal powders. Marshall[168] assessed the mechanical requirements of plant for roll compacting, while Hunt and Eborall[169] described experimental work on rolling of copper powder to strip; electrolytic, atomised and hydrogen-reduced powders were used. In the discussion which followed,[170] Franssen stated that economic conditions at present restricted powder-rolling processes to products which could not be satisfactorily produced by conventional means, while Naeser said that the physical characteristics of powder-rolled material can vary by up to ± 30%; he thought that much further work was required before full-scale commercial application could be envisaged.

In spite of these remarks, a report has appeared[171] of an American mill which can roll up to about 200 lb. of copper powder per hour, the strip produced being said to have 40,000 lb./sq. in. tensile strength, 34% elongation and 101% I.A.C.S. electrical conductivity. Assuming a production level of about 50 tons per day, the average cost of converting copper powder to strip (0·030 in. thick, 18 in. wide) is estimated to be about 2c. per lb., compared with 8c. per lb. for similar strip fabricated by rolling of ingots.

At the Powder Metallurgy Group meeting mentioned, there was also an interesting paper by Deibel, Thornburg and Emley,[172] describing a process of continuous compaction by cyclic pressing. The method is applicable to copper and copper alloys and enables the production of bars of thickness greater than that attainable by direct powder rolling. Forrester and Beddow[173] also gave an account of a continuous method of manufacturing bimetal strip—70/30 copper-lead bonded to steel—by means of a " sinter-compact-resinter " technique.

Other Methods of Compacting Powders

Some recent experiences in the hot extrusion of aluminium bronze powders have been reported by Chadwick,[174] while Montgomery and Thomas[175] have described a technique for compacting copper and other metal powders by the use of detonating explosives under controlled conditions.

Cermets

Beryllia and alumina dispersions have been produced in copper powder compacts by internal oxidation of suitable alloy powders, and density, hardness and compression yield points determined for the compacts after various sintering treatments.[176] Copper powder compacts containing small proportions of alumina, silica or magnesia were recently investigated in Russia.[177]

Physical Metallurgy and Metallography

Alloy Constitution

Although the solubility of tantalum in pure copper is only 0·025% at 1,100° C., Smith[178] found that in the presence of nickel this figure could be significantly increased—the resulting age-hardening alloys having admirable high-strength properties, as outlined in the section of this survey on " Mechanical and Physical Properties." The constitution of the silver-copper-cadmium-tin alloys containing 20% tin has been examined by Gebhardt and Petzow[179] and isothermal sections and solubility limits established. Whilst zinc and nickel together were found to result in a smaller change in the lattice parameter of copper than when added separately, Chadwick and Argent[180] found the opposite to be true for zinc and manganese additions; the degree of ordering is suggested as a possible explanation for this phenomenon.

Precipitation and Diffusion Processes

In an investigation into the type of precipitation occurring in commercial beryllium copper at temperatures between 300° and 550° C., Entwistle and Wynn[181] found a lamellar structure formed between 380° and 560° C. Below this range normal age-hardening processes occur, and above it coarse isolated particles are precipitated. The lamellar precipitation results in decreased strength and hardness, but the TTT curves determined show that the hardenability of the alloy is sufficient to prevent lamellar precipitation during normal quenching. The transformation of eutectoid beryllium copper has also interested other workers.[182,183] Copper-titanium alloys containing up to 6% titanium were found by Buckel and Manenc[184] to pass through two stages before the equilibrium precipitate of Cu_3Ti is formed.

Srinivasan and Anantharaman[185] studied the formation of the alpha phase in brasses containing 36–42% zinc, and also the changes which occur on tempering the supersaturated alpha solid solution. In the copper-gold system, Burghard and Brotzen[186] found that vibrations in the range 5–15 kc/s decreased the rate of ordering over the temperature range of 280°–360° C.

The rate of diffusion of zinc in copper at 550° C. has been measured by Achter and his collaborators[187] using an electronprobe microanalyser, while Britton and Clarke[188] detected the diffusion of small amounts of zinc from brass into tin coatings by measuring the corrosion potential of the tin. They found that flow-brightening or long storage, for example, resulted in detectable amounts of zinc diffusing into the tin which might give rise to corrosion products in a damp atmosphere, sufficient to affect adversely the solderability of tinned brass. During a study of the compatibility of graphite with metals at high temperatures, Gerds and Mallett[189] found copper to be the least affected of all the metals tested.

Grain Structure and Metallography

Grain size measurements were used by Dahl and Geissler[190] to examine the effect of small additions of nickel, silicon, beryllium, aluminium, silver and tin on the recrystallisation of pure copper. In 70/30 brass, Izumi and Yoshiki[191] found that impurities and other variables exerted a much smaller influence on grain size during short-time high-temperature anneals than during conventional batch annealing; other advantages accruing from the rapid heating were a more uniform grain size and reduced scaling.

Kirk and Cockroft[192] revealed some unusual " ghost " grain boundaries in commercial oxygen-free copper by prolonged electro-etching. These " ghost " boundaries were considered to be due to segregated impurities at the grain boundaries before recrystallisation. Since they are continuous with the lattice, they suggest a useful means of observing grain-boundary movement during slow deformation at elevated temperatures. As a result of their experimental work on copper bi-crystals, Intrater and Machlin[193] presented a theory of grain-boundary sliding in which the rate controlling process is boundary migration.

The incidence of strain markings in copper and alpha brass has been studied in some detail by Hatherly[194]

who found the degree of deformation and zinc content of the brass to exert a significant influence on the nature of the markings. Liu and Richman[195] found that additions of germanium and tin, within the alpha-solid-solution range, also changed the deformation texture from that of pure copper to the 70/30 brass-type. To explain the cube-texture in rolled copper, Verbraak[196] introduces the concept of a martensitic-type nucleation in his thesis on the subject. The dislocation structure of copper crystals deformed in bending and in tension has been examined by Livingstone[197] while Meakin and Wilsdorf[198] have similarly studied alpha brass and discussed the agreement between their observations and theoretical predictions.

Surface Oxidation

Rönnquist and Fischmeister[199] have provided a very useful review of the oxidation of copper, based on 160 literature references, a particularly valuable feature being the oxidation isotherms for exposure periods of up to 5,000 minutes. In general, they found good agreement between the higher-temperature results, where the parabolic rate law is obeyed, but at lower temperatures, agreement was not so good. Particular attention was paid by Gronlund[200] to the effect of oxygen pressure on the formation and growth of copper-oxide nuclei at high temperatures.

At 850°–1,000° C., silicon (1 at.%) has been shown by Evans and Chatterji[201] to have little influence on the oxidation of copper. The effect of up to 10% nickel on the type of scale formed on copper at 200° C. was investigated by Bouillon and Stevens,[202] while Blade and Preece[203] covered a much wider range of copper alloys in their survey of the formation of protective scales. An improvement in the high-temperature scaling resistance of the copper-aluminium and copper-nickel-aluminium alloys was observed when silicon, chromium or beryllium was present in the alloy.

Internal Oxidation

The increases in hardness and yield strength of internally-oxidised copper-aluminium alloys were found by Wood[204] to depend on the grain size of the alloy and the oxide particle size. Although the ductility of these alloys is reduced, particularly at high temperatures, it can be improved by recrystallisation. The importance of this effect on the properties of internally-oxidised copper-silicon and copper-beryllium alloys is also illustrated by Seebohm and Martin's[205] work, which demonstrated that more intense oxide precipitation at the grain boundaries, due to solute segregation, could be reduced by introducing preferred orientation into the specimen. The importance of suitable dispersion of the second phase on secondary recrystallisation and grain-growth phenomena is further stressed by Schwartzkopf and Grant.[206]

Analysis and Testing

Analysis

Progress in the modern X-ray fluorescence method of analysis, as applied to copper alloys, has been described by Bareham and Fox.[207] The speed and precision which can be attained by this method are of great value for production control and for determining the major alloying elements as well as impurities. Although there are serious inter-element effects, the use of appropriate reference standards reduces the practical difficulties.

Classical methods for the analysis of copper alloys are being standardised by the British Standards Institution, and those recommended for the determination of copper, lead, iron, aluminium, nickel, tin, silicon and phosphorus have recently been published.[208] The procedures outlined have been found to give reliable and reproducible results and are suitable for test purposes in cases of dispute.

Routine methods of analysis of copper alloys have been described by Versagi,[209] and a fairly exhaustive survey of chemical methods for copper-base materials has been prepared by Donizel and translated into English, sometimes rather quaintly, by Andraso;[210] the text, which is supported by over 750 literature references, discusses the gravimetric, titrimetric, polarographic, and colorimetric methods applicable to the determination of all the usual alloying elements or impurities. A full scheme for the works analysis of a high-tensile brass containing manganese, nickel, iron, tin, aluminium, silicon and lead has been recorded by Klinkmann.[211]

Tuck and Osborn[212] have examined colorimetric methods for the direct microdetermination of copper in water and have concluded that 2 : 2′–diquinolyl is the best reagent, as the usual interfering elements such as iron, zinc, etc., have no effect.

Testing

James[213] has surveyed the technique of hardness testing and its use in the production of copper and copper alloys as sheet and strip material; he discusses the various factors which influence the results. In America, an ultrasonic tester is being used to check the laminate strength of stainless steel-copper-stainless steel cladmetal "sandwich" discs.[214]

A technique for measuring eccentricity in metal tubes has been described by Noltingk,[215] whereby variations in thickness are gauged by the screening effect of the walls on coils located inside and outside the tubes. Burd[216] has indicated how small defects in tubes can be readily located by a new eddy-current testing machine which explores the whole tube by eddy currents induced by a radio-frequency field.

Meleka[217] has modified a commercial creep-testing machine so that both creep and fatigue tests can be performed simultaneously, while two volumes have been published[218] containing a comprehensive account of the large number of non-destructive tests now available.

Building and Plumbing

Solar Heating and Cooling

Solar water heaters have found wide application in certain warm countries, both for domestic and industrial uses[219]; the heaters consist of two metal sheets, between which are coiled copper pipes leading to a water tank containing a copper heat exchanger. The water is pump-circulated. Blanco[220] has discussed the design, installation and economic aspects of such domestic heaters, incorporating copper "tube-in-strip" material, and a description has been given[221] of a unit in operation for heating an open-air swimming pool in England. For solar space cooling, an energy collector is assembled from copper sheets with built-in water tubes and a blackened surface;[222] an ordinary absorption cooler system has to be supplemented by more heat-exchange surface than is usual in fuel-operated cycles.

Plumbing

Charge[223] has described capillary jointing of copper tubes for domestic plumbing, advocating the use of copper-silver-phosphorus brazing alloys to overcome the possibility of dezincification of duplex brazing brasses in some supply waters. The author describes recently-developed tools for the production of sockets and branches to the tolerances required for successful brazing.

Copper Salts and Compounds

Voisin[224] in his book "Soil, Grass and Cancer" has developed his theory that the health of animals and men is linked with the mineral balance of the soil. He cites examples of disease attributable to variations of mineral content, and devotes several chapters to the part played by copper in the soil, relating this particularly to an alleged connection between copper deficiency and cancer. An account of the addition of copper sulphate to grazing land in Australia to overcome copper deficiency in sheep and the consequent occurrence of "steely wool" has been given by Jefferies.[225] The use of copper sulphate as an ingredient of meal mixtures for fattening pigs in Northern Ireland is now normal, according to Coey.[226]

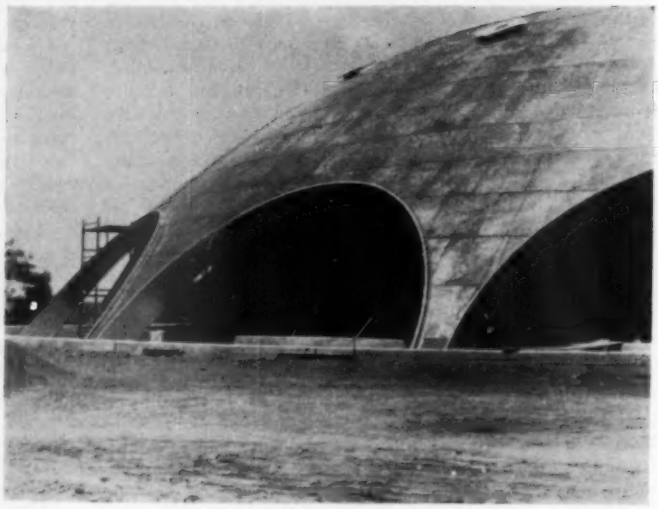
Though the use of copper compounds for seed treatment has decreased in many countries, they are suggested for cotton seeds by Shver[227] in Russia, and by Aleksiev[228] for tobacco in Bulgaria. In the latter case, the addition of the copper compound to the soil when the seedlings are being planted out is also recommended. In Northern Rhodesia, Lynn[229] reports that during 1957-58, when conditions favoured the infection of ground-nuts by *Cercospora personata*, spraying with Bordeaux mixture gave a yield of 1,436 lb./acre, compared with only 636 lb./acre when spraying was omitted.

Miscellaneous

The development of "fibre metallurgy" by the adaptation of paper-making techniques has been described by Morden.[230] A slurry containing fine metal fibres is used to form a low-density felt which, after sintering, can be fabricated by a variety of processes including welding, machining and rolling. Copper fibres are among those investigated and copper-plated steel fibres have been found to provide much stronger fibre bodies than unplated fibres. By contrast McDanels, Jech and Weeton[231] have described the use of tungsten fibres embedded in copper to improve its tensile strength; 25% tungsten, for example, is reported to produce a material approximately three times stronger than copper itself.

A method of reinforcing plastics with filaments or ribbons of metal, including copper and copper alloys, has been reported.[232] The filaments are cast from molten metal and are up to 2 in. in length, with diameters ranging from 0·00025 to 0·010 in. In a method of producing similar filaments, developed by Pond,[233] streams of molten metal are brought together to form bimetallic filaments including copper-iron, copper-nickel and copper-aluminium.

With the first American Standard on metal hose now in course of preparation, Donkle[234] discusses the effect of pressure, temperature, temperature gradient and the shock factor upon the design of hose, including types made from cupro-nickel, brass and bronze.



Part of the dome of the new Australian Academy of Science Building which is completely clad with copper.

A new approach[235] to the protection of metal surfaces during manufacturing operations is the use of transparent unplasticised vinyl films or tapes coated with a special low-tack adhesive to facilitate removal. The tape is available in rolls up to 24 in. wide, and an inhibitor is incorporated in the adhesive to give increased protection to copper, brass, bronze and other copper alloys. Suggested applications include the preservation of clean surfaces on copper-clad laminates for printed circuits.

Investigations at the Armaments Research and Development Establishment[236] have shown that a graphite film provides the most satisfactory method of protecting brass fuses against corrosion during storage in adverse environments. Other work at this Establishment includes the development of plasma jet torches with copper or graphite nozzles which can be used for cutting molybdenum and tungsten and for flame-spraying alumina and other refractory materials.

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News in Brief

EFCO FURNACES, LTD., have received orders for further extensions to their furnace installation at The United Wire Works, Ltd., Edinburgh. The orders cover the supply of a 200 kW. pit pot furnace for bright annealing 8 ton charges of phosphor bronze wire and a bell furnace installation with two 200 kW. furnaces and eight bases.

THE FIRTH CLEVELAND GROUP, through its subsidiary Firland Metals, Ltd., has acquired Messrs. Quirk, Barton & Burns (St. Helens), Ltd., of St. Helens, Lancashire, manufacturers of sheet lead, lead pipe, solder, laminated lead and other products. Primarily the acquisition was made to reinforce R. E. Roberts & Son, Ltd., of Bolton, another company in the Firth Cleveland lead division.

THE GRIFFIN & GEORGE GROUP have opened in the Bristol area a new sales centre comprising some 5,000 sq. ft. of warehouse, offices and showrooms. The centre is under the management of Mr. W. J. Smith, and all orders and enquiries should be addressed to Griffin & George (Sales), Ltd., Clothier Road, Brislington Trading Estate, Bristol, 4. Tel.: Bristol 70346. Telex: 44267.

MAGNESIUM ELEKTRON, LTD., have announced a reduction in price of their grade IV pure magnesium powder from 6s. 1d./lb. to 5s. 6d./lb. delivered customers' works in the United Kingdom.

A NEW plant for producing liquid hydrogen and/or liquid helium is now in service at the British Oxygen scientific division, Morden, Surrey. It will help the scientific division to meet the rising demand from industry and research bodies for the two liquefied gases. The first plants in the United Kingdom for producing liquid hydrogen and liquid helium on a commercial basis began operating at Morden during last year.

THE new plate mill of Consett Iron Co., Ltd., will be formally opened by the Rt. Hon. Lord Mills, K.B.E., H.M. Paymaster General, on 26th April, 1961.

New Laboratory for London Transport

Improved Facilities for Scientific Services

WITH the official inauguration last December of London Transport's new research laboratory at Chiswick, the scientific staff of the research department has been brought together under one roof for the first time. The laboratory will be the centre for the scientific control and investigation of materials and equipment used throughout London Transport's road and rail services. The new laboratory, with an adjacent single-storey annexe, will accommodate a staff of about eighty of all grades. This represents the whole of the staff under the control of the superintendent of laboratories, except for those employed in small laboratories attached to each of London Transport's three electricity generating stations and one individual who is permanently attached to Aldenham Works. The facilities include a cold chamber for low-temperature testing of materials, a specially-designed screened room for radiographic work, heat-treatment furnaces and welding equipment, a pilot plant laboratory, special recording equipment for strain gauge tests, and a fatigue testing machine for railway car axles.

London Transport spends more than £15 million a year on stores and materials and an important part of the work of the small but highly-specialised research department is to carry out regular routine investigations of these supplies. It is also responsible for the technical control of certain works processes. As its name implies, the department carries out special research work of great value. Among the consequences of these investigations in the last few years are a saving of £300,000 a year in diesel fuel for buses arising from experiments in the use of a thinner grade of lubricating oil, a further saving of £80,000 a year from improved types of rear axle oil for buses, and £50,000 a year saved by work which has led to the doubling of the life of bus batteries. Paint investigations have made it possible to lengthen the repainting period for buses to once in four years, enabling the number of " spare " buses to be reduced and painting costs decreased.

The Work of the Laboratory

The cardinal feature of the work of the Laboratory is its wide variety, not only in respect of the materials handled and technique employed, but also in its nature and purpose.

Much of the work is of a non-repetitive character, but there are also many continuous activities. Among these may be mentioned the control of quality of supplies of all types of materials, ranging from metals to adhesives. This involves the preparation of material specifications for use as the basis of contracts, etc., advising the Supplies Department on the relative merits of alternative products, and the testing of samples of deliveries to ensure maintenance of prescribed standards. Another branch of regular work consists of technical control and advisory services in relation to works processes, such as metal protection, cleaning, spray painting and stove-enamelling, welding, heat treatment and electrodeposition. Further examples of well-defined activities are the constant examination of factors affecting fuel consumption of buses, and the system of checks maintained to ensure that exhaust emission from these vehicles remains unobjectionable.

Much attention is given to keeping abreast of the latest technical developments in all types of materials and processes, with a view to assessing their likely interest to London Transport at the earliest possible stage. Thus, work is always in hand with new developments in such fields as surface protection, lubricant additives, plastics and textiles. Well-established collaboration with using departments facilitates the conduct of works and service trials with those items which

appear promising as a result of preliminary laboratory tests.

Perhaps the largest group of activities consists of the *ad hoc* investigation of day-to-day problems. The matters investigated may include such diverse items as failure of metallic components, lubrication difficulties, water leakages, defects in air systems, unsatisfactory paint application, ticket issuing machine performance, deterioration of rubber, corrosion of metals, staff complaints, and the provision of information required by the medical department.

Longer term investigations in the nature of technical research are also undertaken, frequently involving the careful planning of service experiments in conjunction with laboratory work. Illustrations are provided by the well-known activities of the laboratory in the field of lubrication, such as the pioneer work on the use of low viscosity engine crankcase oils and special rear axle lubricants which has led to significant fuel saving in bus operation ; work on the design and construction of lead acid accummulators ; and the measurement and analysis of stress loading of railway equipment under service conditions. In planning the new laboratory, the aim has been particularly to promote the further development of this aspect of the work.

Apart from various ancillary activities, the work of the research laboratory is divided between five sections and one sub-section. Those aspects of interest in the metallurgical field are briefly described below, and passing reference is made to the work of other sections.

Metallurgical Section

This section is responsible for investigations concerned with all classes of ferrous and non-ferrous metals used by London Transport in road and rail vehicles, permanent way, generating stations and in civil engineering structures. The section is concerned with matters such as the recommendation of appropriate materials for particular components ; advice on avoidance of design features likely to lead to fatigue fracture during service ; examination of failed components and recommendations for changes in design or material to avoid further failures ; and technical assistance and advice on various workshop processes such as welding, electroplating and heat treatment. The section is also responsible for routine checking of deliveries of metallic raw materials and components to ensure compliance with the appropriate specifications.

Many of the specimens handled are of relatively massive size, e.g. railway axles and rails, and the services of a machine shop are available to facilitate the preparation of samples for analysis, sections for microscopic examination, and test pieces suitable for either miniature or full-size mechanical testing equipment. The equipment of this machine shop may also be used in the construction of special laboratory test rigs and apparatus needed by laboratory as a whole. The machine shop staff also undertake maintenance of appropriate laboratory equipment.

The section includes a chemical laboratory devoted to metal analysis and related work such as the control of nickel, chromium, tin and lead electroplating solutions. Because of the wide variety of metals encountered, classical methods of chemical analysis continue to be used to a considerable extent, but the improved accommodation now available will facilitate investigation of the potentialities of physical methods of analysis with a view to their adoption where advantages can be established. To this end a separate small laboratory has been provided for spectrophotometric work, etc. The opportunity has been taken to acquire up-to-date electrolytic analysis apparatus using magnetic stirring in place of the mechanically-stirred equipment previously employed.

A group of three small inter-communicating rooms provides for metallographic work. The largest of these houses a mounting press and equipment for preliminary polishing of microsections as well as facilities for micro-etching. One of the smaller rooms contains equipment for final polishing, using diamond grit, and the third room houses a projection microscope, a binocular microscope, a stereoscope microscope and a viewer for X-ray films. A separate small laboratory fitted with a low-level fume cupboard is provided for macro-etching, sulphur printing, etc.

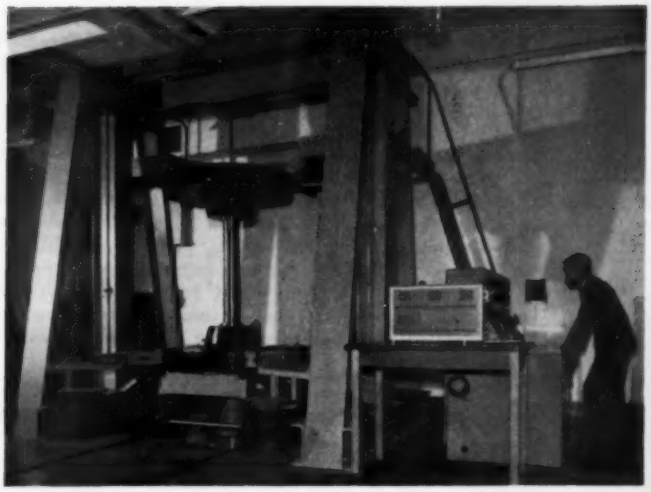
The mechanical testing laboratory is equipped with 12½ and 30 ton tensile testing machines, an Izod impact tester, a Vickers hardness testing machine and a power-operated Brinell hardness tester. A Hounsfield Tensometer is also used to a considerable extent, as it is often impossible to prepare full-size test specimens from components submitted for examination.

The move to new premises has made possible the provision of equipment for radiographic examination of metals, a facility not previously available to the laboratory. This comprises a suitably screened room having internal dimensions of 20 ft. × 18 ft. × 14 ft. high, housing a 260-kV. X-ray tank unit, the controls of which are located in an adjacent control room, interlock switches being provided so as to ensure that the X-ray unit cannot be put into operation until the doors of the screened room are closed. The radiography room is of a size which will accommodate such structures as it is envisaged may require to be examined in the laboratory, but the equipment is of a portable type so that, when necessary, it may be used for X-ray examinations undertaken on site. The radiography room has also been designed so that it can be used for gamma radiography if desired, and a suitable well has been provided within the room for housing a radioactive source. The radiographic equipment is expected to be of particular value in connection with the inspection of welded and cast components, and will also facilitate the periodic examination of welders' test specimens which the laboratory is called upon to undertake as a method of controlling quality of welding.

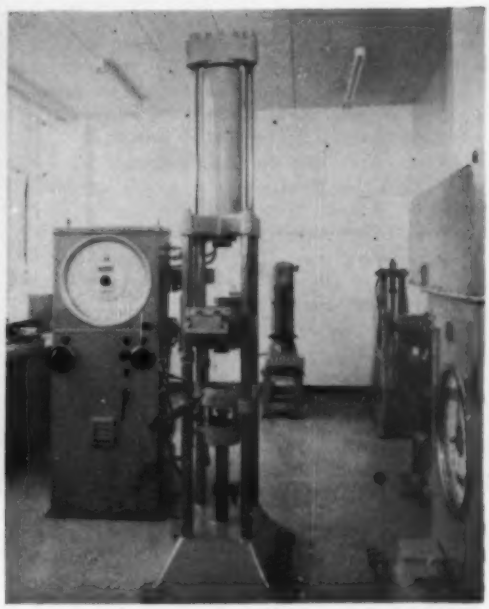
A further innovation made possible by transfer to the new premises is provision of equipment for heat treatment trials and welding tests. The heat treatment equipment consists of an electric muffle unit with pre-heating and high temperature chambers and apparatus for providing a controlled atmosphere together with the quenching tanks required for hardening ; a small forced-air circulation tempering furnace ; and a gas-fired furnace for heat treatment of welded assemblies. For welding tests, 300-A. and 150-A. A1 welding sets are installed in a cubicle equipped with a portable extraction unit. A heated electrode cupboard is also provided for storage of welding electrodes.

Chemistry in the Research Laboratory

Work of a chemical nature is a major element in the activities of the research laboratory and chemical



Resonant fatigue test machine for submitting axle-sized steel specimens to rotating bending stresses such as are encountered in service. Console on right incorporates motor clutch control equipment, strain measuring apparatus and necessary safety devices.



Mechanical testing laboratory showing, from left to right, 30 ton Avery tensile testing machine, Brinell hardness tester, Izod impact tester, Vickers hardness machine, and 12½ ton Denison tensile testing machine.

laboratories are attached to the metallurgical, fuels and lubricants, and paints sections. A large volume of chemical work, however, falls outside the scope of such specialised sections, and is dealt with by the general chemistry section.

The salient feature of the work of this section is its wide variety. Chemical analysis of virtually any type of material may be involved, as well as investigations into the most diverse problems. Products dealt with in the section include detergents, adhesives, inks, disinfectants, abrasives, plastics, weed killers, and papers, but the list could be extended almost indefinitely. Samples of effluents, waters, etc., are frequently examined, and routine control is exercised over solutions used in various works' processes. Typical examples illustrating the range of investigations undertaken have been those concerned with the identification of sources of leakages into tube tunnels, the determination of small concentrations of toxic gases and vapours, the origin of fires, the cleaning of mechanical components, the determination of lead and vanadium in urine, and the prevention of corrosion in water-cooling systems of internal combustion engines.

In the new premises, two adjoining chemical laboratories have been provided for this work. The larger of the two, which is intended to cater for the commoner types of activities, provides ample accommodation for six workers and is generously furnished with a variety of fume cupboards, furnaces, ovens, hot plates and other essential equipment. The smaller laboratory offers excellent facilities for two workers engaged on work of a more unusual or longer term character. A balance room housing two single pan aperiodic balances is readily accessible from both laboratories.

Axle Fatigue Testing Machine

A major item of equipment in the new laboratory is an axle fatigue testing machine which has been specifically designed to investigate the fatigue strength of railway car axles. The machine has been developed at Nottingham University to determine the strength of specimens of axle steel when subjected to a rotating bending stress. There is a "scale effect" of uncertain magnitude in fatigue, and so the machine is designed to test specimens of typical axle sizes, viz. 6½ in. diameter. It is intended initially to investigate the effects on fatigue strength of surface rolling, with and without subsequent light machining and, later, the effect of shrink fits. The influence of steel composition will also be investigated.

The machine is of the resonant type with a mechanical drive via a slipping clutch to permit starting and stopping. The specimen is about 5 ft. long by 6½ in. diameter with enlarged ends. Each end is secured in a heavy disc. The assembly of two heavy discs and the specimen as a spring has a natural frequency for transverse bending of the specimen just below 50 c./s. The assembly is freely suspended from the centre of one disc by a wire rope with the specimen vertical. The lower disc carries below it a rigid extension tube. If the lower end of this tube is caused to move in a circular path at a speed corresponding to the natural frequency the assembly is caused to vibrate and so give a rotating bending stress on the specimen.

The drive is from a 25 h.p. D.C. motor below floor level. It is supplied from a Ward-Leonard set to provide variable speed. The motor drives a vertical shaft with an eccentric stub shaft at the upper end. The eccentricity is adjustable (in order to vary the applied stress) and the design is such that the rotating assembly remains balanced at all settings of the eccentric. The circular motion of the centre line of the stub shaft is transmitted to the lower end of the specimen-disc-tube assembly by means of a bearing and friction drive. This takes the form of a special hydraulically-operated clutch and is

used to prevent excessive forces being applied during starting and stopping when the speed does not coincide with the resonant frequency. The stress is measured by resistance strain gauges, calibrated in position, and a number of protective devices are included so that the machine may be left running unattended.

Of the first two specimens tested in the machine, one failed at a stress not much greater than the expected fatigue limit (2,910,000 cycles at 16 tons/sq. in. : the other failed at a higher stress (640,000 cycles at 20 tons/sq. in.). Both specimens were subsequently broken open by static bending to expose the fatigue fractured surfaces.

A related investigation dealing with residual stress distributions in cold-rolled railway axle wheel seats is being carried out at Nottingham University. In view of its common interest to British Railways and London Transport, this investigation is being sponsored by the British Transport Commission's Research Co-ordination Committee. The explanation of the improved fatigue properties obtained by cold rolling is briefly that residual compressive stresses are obtained in the surface layers where the applied stresses are a maximum, and such residual stresses counteract the dangerous tensile stresses which arise due to service conditions. Little information is available regarding the actual beneficial residual stress patterns existing in the *surface layers* of the wheel seatings, or the effect of such variables as rolling load, axle steel composition, heat treatment and size upon both the residual surface stress distributions and the fatigue properties of the axle.

The investigation has so far shown that

(*a*) The maximum compressive residual stresses induced by cold rolling occur at the surface and not subcutaneously as had previously been thought.

(*b*) Cold-rolled oil-quenched and tempered axles give slightly higher compressive residual stresses than normalised axles rolled under corresponding conditions.

(*c*) The maximum compressive stresses occurring at the surface are slightly increased with increase in carbon content—for similar rolling conditions—within the normal range of axle steel compositions (0·25–0·4%).

(*d*) A small alloying addition (1·5% Mn) also gives a slight increase in the maximum compressive residual stress for axles in either the normalised or quenched and tempered states.

The investigation is at present concerned with the effects of rolling load upon the residual stress distributions in the surface layers, the effect of wheel seat diameter on the distributions and the plastic flow caused by the rolling operation.

Other Sections

Paints.—The paints section is concerned with paints used in both road and rail vehicles, and on buildings, structures, etc. Methods of application, and the necessary preparatory processes, are studied as well as the materials themselves. The object is to achieve the highest possible standard of appearance and of protection against corrosion and other forms of deterioration, whilst minimising maintenance costs and the need for withdrawing vehicles, etc., from service.

Fuels and Lubricants.—This section is concerned with liquid fuels, lubricants of all types, transformer oils, and various other petroleum-based products. On the fuels side, the main accent is on fuel for diesel-engined buses, although the materials dealt with include petrol, kerosene, and under-boiler fuels. With regard to lubricants, the range of applications is very extensive, since London Transport operates a wide variety of mechanical equipment, from heavy items of plant to clocks and other delicate mechanisms. The range of lubricants handled is correspondingly wide, embracing plain and additive treated oils of many types, numerous categories of grease, and products incorporating solid lubricants. Bonded lubricant coatings, special surface treatments designed to reduce friction, and self-lubricating materials are also involved.

Physics and Engineering Section.—This section is concerned with measurements of the mechanical and electrical properties of many types of non-metallic materials ; with the development and application of non-destructive test methods of examination of engineering components ; and with investigations into the behaviour of items of equipment under conditions in service and under controlled laboratory conditions, respectively. The section undertakes on behalf of the laboratory as a whole the design and construction of many special items of equipment which may be needed, and also makes calibration checks of electrical instruments, pyrometers, etc., on behalf of other departments. A motored axle with strain gauges and slip rings has been fitted to a District Line car and used to study the variations in bending stress induced when traversing straight and curved track, points and crossovers under service operating conditions. In this way information will be obtained to guide the section in drawing up a programme of work for the axle fatigue testing machine described earlier, which comes under the jurisdiction of the physics and engineering section.

Alumina Plant in British Guiana

IMPORTANT new facilities for the manufacture of alumina in British Guiana, on the North East coastline of South America, were officially inaugurated last month by the Hon. Dr. Cheddi Jagan, Minister of Trade and Industry. The occasion was the first shipment of alumina from the Demerara Bauxite Co., Ltd.'s 230,000 tons p.a. alumina plant at Mackenzie, 60 miles up the Demerara River from the Atlantic and accessible to seagoing freighters.

Incorporated in British Guiana in 1916, Demerara Bauxite Co., Ltd., is one of several bauxite mining companies which supply Aluminium Ltd.'s smelters in Canada and other countries with the basic raw material. The company also sells calcined bauxite to manufacturers of refractories and abrasives in some twenty-five different countries. It will continue its role as a bauxite supplier in addition to shipping alumina processed from local bauxite. With the completion of the new alumina plant Aluminium, Ltd., will have invested over W.I. $100 million in British Guiana, an effective measure of the company's faith in the future of the country. The coming into production of the plant in British Guiana completes Aluminium, Ltd.'s development of a raw material base sufficient to support an eventual aluminium smelter capacity in Canada of the order of 1 million tons per annum.

Installation for the Preparation of Steel Blanks for Cold Forging

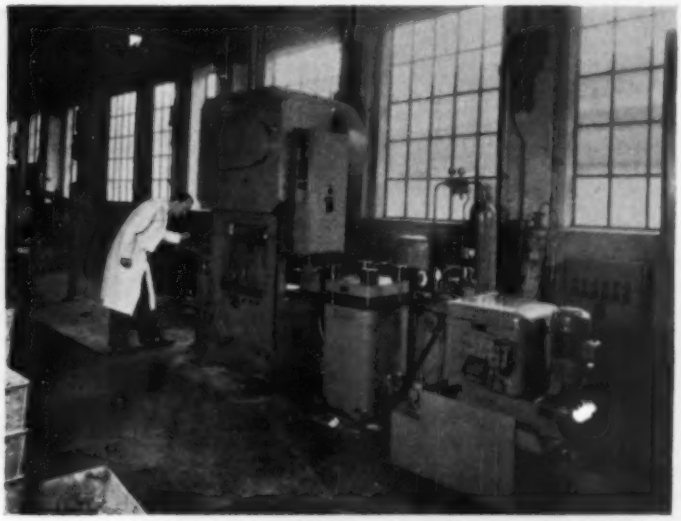


Fig. 1.—The automatic cropping (left-centre), preforming or flattening (centre), and chamfering (right) installation at the Sunbury works of Cold Forging Ltd.

AN installation which will produce, continuously and automatically, steel blanks of uniform mass and shape has been designed and developed by Cold Forging, Ltd., a member of the Camp Bird group. Three distinctly separate operations may be carried out, including cropping from bar-stock, flattening or preforming of the cropped blank, and deburring or chamfering of the inevitable cropping burr. The three units—which are included in the company's series of machines marketed under the name Colforg—are linked to one another by a mechanical conveyor belt which feeds the blanks from one unit to the next. Fig. 1 shows an installation for preparing blanks for cold forging at the Sunbury-on-Thames works of Cold Forging, Ltd., which is completely automatic except for placing the bars of raw material on the bar-stock feeder.

Cropping

In designing the equipment, the unit-construction principle was applied wherever possible, to enable the potential customer to buy a plant 'made to measure' to his own requirements, although it consists of standard parts. This applies not only to individual machine components, but also to some of the machines themselves, e.g. to the cropping machine.

The cropping machines are made in three sizes capable of handling bar-stock of 1, 2 and 3 in. diameter, respectively. However, in the interests of overall operational efficiency it may be desirable to use the cropping machine with a special tool which will also carry out the flattening operation. The power required for flattening blanks of a given diameter is substantially greater than that required to crop bar-stock of the same cross-section. The cropping machine can, therefore, only be used to crop and flatten material of a smaller cross-section than the maximum rating of the cropping tool.

The bar-stock feeder for the machines is a standard unit, irrespective of whether the machine operates exclusively as a cropper or as a combination flattening cropper. The individual bars are placed on an inclined bed fitted with rails, on which runs a carriage which is attached by wire cable to a hydraulically-operated drum. The front of the carriage engages the end face of the steel bar, so that when tension is applied to the rope, a positive feed is applied to the bar, which is moved successively into the cropping tool at the operating rhythm of the machine. The hydraulic system is under permanent constant pressure, even when the bar has been advanced against the fixed stop of the cropping tool, thus applying a continuous but flexible pull, which ensures accurate feeding.

Preforming

In the installation shown in Fig. 1, the cropped blank is gripped by a transfer conveyor which moves the blank to the next machine of the installation. This conveyor system consists of two positively driven chains provided with carrier dogs arranged to face each other. The relative spacing of the chains can be varied simply by adjusting the rails on which they run, thus providing the necessary adaptability to handle blanks of different size. The carrier dogs of each chain are always positioned opposite each other so that the space between the carrier dogs forms a positive pocket from which the blank cannot escape, and in which it is moved at the correct operating rhythm to the next processing stage, in this case the preforming machine. The conveyor carrying the cropped steel blanks passes through the preforming tool and then carries the preform to the chamfering machine, where it is dropped into a chute. The conveyor then returns to the cropping machine, passing underneath the preformer in its passage.

The preforming machine consists of a frame with an overhead platen mounted on four columns. The blanks enter the machine and are flattened by the upward movement of a ram to a fixed stop. The ram is hydraulically driven from a self-contained hydraulic unit which is coupled to the machine and located next to it. The hydraulic unit consists of the reservoir with hydraulic

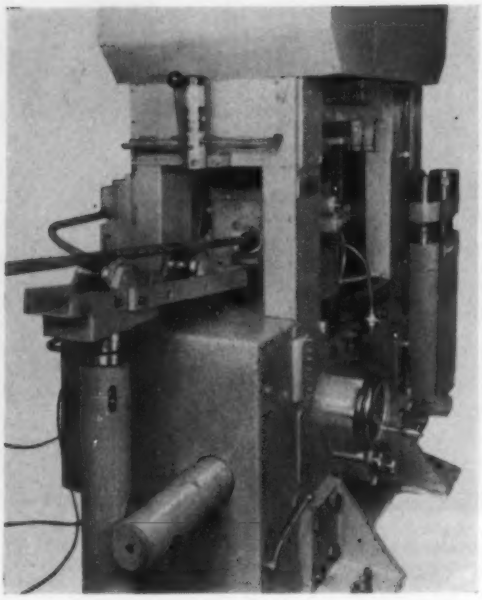


Fig. 2.—Close-up of the entry side of the cropping machine.

pump and valves as well as the prefilling cylinder and the necessary controls and monitoring instruments.

The operating cycle of the preforming machine is linked to that of the cropping machine by an electromagnetic clutch driven by the feed chain on the discharge side of the cropping machine. This clutch actuates the solenoid valves which in turn control the operation of the preforming machine. The clutch control unit is also a standard item which can be fitted to other machines of the series. The preforming machine can be fitted with a simple flattening tool or it may be fitted with different tools which will impart an initial shape to the blank to facilitate easier development of the final form of the forging by subsequent cold forming operations.

Deburring

After completion of the flattening operation, the blanks are transferred by the same conveyor to the deburring machine. They enter the actual working zone of the machine on a pan-feeder, after which they are advanced to the chamfering tool by spring-loaded roller fingers, which press the blank against the tool, so that the movement of the blank along the tool takes the form of a hobbing action. The actual chamfering tool takes the form of a bevelled inverted milling cutter, whose operating depth can be varied by a simple handwheel adjustment. This method of operation ensures that a uniform amount of chamfer is applied to blanks having a somewhat irregular periphery, as would be expected from raw material consisting of rough-rolled bar-stock. The machine is independently driven by its own electric motor and includes provision for continuous separation of swarf from the coolant. Both the coolant tank and the coolant pump are integral parts of the machine.

The blanks are in contact with the deburring tool for approximately one half of the circumference, the depth of engagement varying between minimum and maximum

Fig. 3.—The cutting head of the chamfering machine.

over this distance. The completed blanks are automatically ejected from the machine through a chute, and are ready for intermediate heat treatment and for surface treatment in a phosphate bath, before the cold forging operation.

The entire installation is controlled from a cabinet which can be seen in the background of Fig. 1. Each machine is provided with safety devices which immediately stop all linked units of the system in the event of broken tools, defective blanks or feeding faults, etc.

Flexible Arrangement

The installation and its individual units, which can of course all be used separately in a variety of different combinations, is very flexible and versatile. This is an important requirement of modern production techniques, in order that extension and modification of plant to suit different requirements may be fully met. Thus, the units of this installation need never be idle as a result of a change in the production programme, while further extension of the programme or a greatly increased output requirement can easily be met by a re-combination of the units with transfer mechanism and other items which are already standardised.

Birlec in Australia

An agreement has been made between AEI-Birlec, Ltd., of Birmingham and Major Electric Furnaces Pty., Ltd., of Melbourne, Australia, for the setting up in Melbourne of a new company to be known as Birlec-Major Pty., Ltd., with offices in Chesterville Road, Moorabbin, Melbourne. Birlec-Major Pty., Ltd., will manufacture every type of electric and gas fired furnace, for heat-treatment and melting processes, at present built by Birlec and their associate companies in the U.K. In addition to serving the Australian market, the new company intend to market their products in New Zealand and S.E. Asia Since 1952 Birlec furnaces have been manufactured under licence by Major Electric Furnaces Pty., Ltd., and are installed in most Australian industries. However, this agreement now terminates with the formation of the new company, which strengthens the technical and specialist design services available to Australian firms.

Quality Control in Sheet Production

New Classifier Developed by English Electric

A new quality control system for the sheet steel and tinplate industries is being produced by the metal industries division of English Electric Co., Ltd. This new sheet metal classifier is used for sorting sheared sections of cold strip and rejecting faulty pieces.

Faults such as pinholes, off-gauge and poor surface finish are detected during the inspection of the continuous strip, but the sorting into grades can only be done when the strip has been cut into individual sheets. The sheet classifier stores the information on strip quality obtained at the time of inspection and uses it when the sheet is cut and ready for sorting into piles. The information is stored and processed by Datapacs—standard transistorised logical elements. From these standard elements a sheet classifier system of any size and complexity can be built, for a line of any speed and with cut length ratio of as much as 10/1.

The first units will shortly be installed on No. 5 cut-up line at the Abbey Works of the Steel Company of Wales, Ltd., and on two cut-up lines at Richard Thomas & Baldwins, Ltd., Ebbw Vale. A further unit is to be installed in a South African steelworks. The unit at the Abbey Works will be on a steel line operating at 700 ft./min. with cut lengths ranging from 40 in. to 180 in. Sorting will be into rejects and prime sheets. On two tinplate lines at Ebbw Vale, both operating at 1,000 ft./min. and with cut lengths ranging from 18 in. to 42 in., sorting will be into four piles: sheets with pinholes, off-gauge material, other rejects, and prime sheets. A simplified working model of this system was shown at the recent Electrical Engineers (A.S.E.E.) Exhibition, at Earls Court.

Method of Operation

The Datapac standard logical elements are in the form of plug-in packages, each containing a number of elements capable of performing a specific logical function, e.g. shift register, "and" gate, store etc. Each element can operate from the output of the preceding element, so that a series of elements can be made up to form any desired logical system.

Faults detected by the instruments are stored in the first shift register at a point corresponding to the instrument position. Shift pulses timed to the conveyor movement are applied to the register so that the fault signal moves within it in time with the movement of the faulty section of strip on the shearing line. The signal transfers from the register to "store 1" when the fault

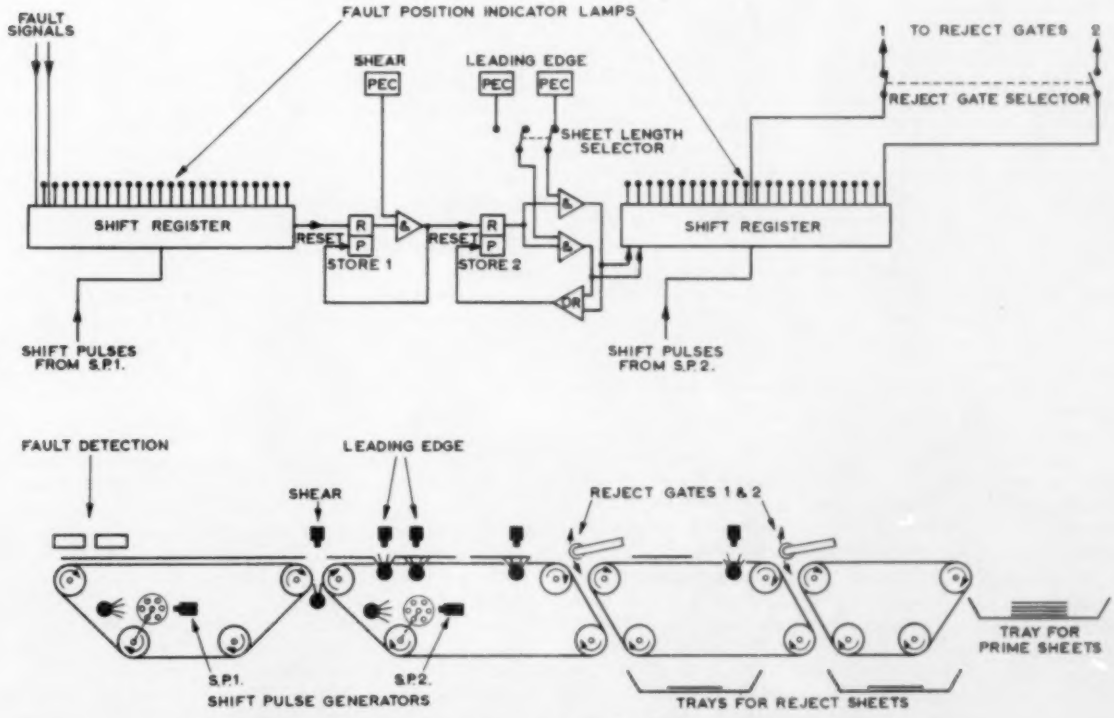


Diagram showing operation of a typical sheet metal classifier.

passes the shear position. This then indicates that the next sheet to be cut is a reject.

When a sheet is cut, this is detected by a device which causes the signal to be transferred from "store 1" to "store 2". This indicates that the last sheet cut is reject. The leading edge of this reject sheet is now detected by one of the leading edge detection photocells and transferred to a suitable position in the second register. The signal of the reject sheet is then shifted within the second register so that it appears at a reject gate just before the leading edge of the sheet reaches the gate. The signal is used to prime the gate control to reject the sheet when its leading edge reaches the gate photocell.

Two leading edge photocells are used after the shear to cover the range of sheet lengths used. One is used for short sheets, the other for long sheets. Either is suitable for sheets of medium length. Selection of the photocell is automatically done by the shear cut length setting.

Normally mechanical reject gates are used, but more complex methods such as overhead magnetic conveyors with variable drop off points for the piles can be operated with the new system.

The Rapid Desulphurising of Steel

THE refining period in the electric arc furnace, that is the time in which the molten metal is held under a white reducing slag for sulphur removal, is also the time when the hydrogen content of the steel can increase to undesirable levels. For very low sulphur steels extremely long refining times are normally necessary. It is possible, however, to speed up this process and so reduce the danger of hydrogen contamination.

BISRA'S Steelmaking Division has carried out a number of experiments in which powdered desulphurising reagents were injected directly into the metal bath of an electric arc furnace to bring about rapid sulphur removal. The experiments were divided into two groups :

(1) Injections into the metal with only a minimum of slag present, leaving the reaction products to form a new slag on the surface of the metal.

(2) Injections under a white reducing slag.

The injections under a minimum of slag were carried out to show the degree of desulphurisation obtainable with a particular reagent, and the injections under white reducing slag were carried out so that the rate of desulphurisation with each reagent could be measured. The powdered reagents used for these experiments were burnt lime, burnt lime plus carbon, calcium cyanamide, calcium carbide, Raremet Compound No. 5, calcium silicide, and calcium silicide plus burnt lime. Mixtures of these, together with either powdered aluminium or magnesium, were also injected.

For the injection under a minimum of slag, the metal bath was put under a white reducing slag in a 10 cwt. electric arc furnace until the sulphur concentration of the metal was reduced to approximately 0·015%. Then the slag was removed almost completely and the desired quantity of powdered reagent, with or without deoxidiser, injected into the bath through ½ in. Class C tubing with oxygen-free nitrogen as the carrier gas. The reaction products from the injection were left on the surface to form a new slag. A British Oxygen Gases powder dispenser was used for the injection. In each experiment the lancing was divided into several parts so that the course of the reaction could be determined.

For the injections under slag, the metal bath was put under a white reducing slag in the electric arc furnace. Metal and slag samples and temperatures were taken at regular intervals so that the rate of desulphurisation for the slag could be determined. The desired quantity of powdered reagent was then injected and a metal sample, a slag sample and a temperature reading were taken as soon as each injection was complete. The materials used for these injections were calcium-silico-magnesium, calcium-silico-manganese, calcium silicide and burnt lime plus magnesium powder.

The results of the two series of experiments show that steel can certainly be rapidly desulphurised to low levels by the injection of powdered reagents ; but for quick desulphurisation to very low levels the metal must be strongly deoxidised, either by previous treatment—for example, with aluminium—or by the injectant containing magnesium or aluminium, either as an alloy or as an element. Magnesium powder can be safely dispensed when it is suitably diluted with other powdered materials.

Reproducible sulphur values of approximately 0·005% were obtained by the injection of calcium carbide or calcium cyanamide into aluminium-deoxidised metal baths, and also by the injection of mixtures of calcium carbide, calcium cyanamide or burnt lime with magnesium powder into ferrosilicon-deoxidised baths under the minimum of slag.

The most rapid desulphurisation to very low sulphur levels under white reducing slag was achieved when burnt lime with magnesium powder mixtures and calcium-silico-magnesium were used as the injectants. The rate of sulphur removal during these injections varied from 0·003 to 0·007 % per minute. Negligible change was found in the sulphur concentration of the treated metal on tapping.

Full details of these experiments, including the chemical reactions, approximate costs of injection on an industrial scale, total cost per ton of steel treated, and two comprehensive tables of metal and slag analysis plus injection rates, can be found in BISRA report SM/AC/46/60, obtainable from the Information Officer, the British Iron and Steel Research Association, 11 Park Lane, London, W.1.

PFIZER, LTD., and its subsidiary Kemball, Bishop & Co., Ltd., have entered into an agreement with Diversey (U.K.), Ltd., under which the latter handles all sales in the United Kingdom of sodium gluconate or gluconic acid, when required for use in bottle-washing or aluminium etching in the United Kingdom. Diversey holds patents Nos. 771,791, 771,792 and 731,035 covering the use of sodium gluconate or gluconic acid in these fields. Pfizer, Ltd., wishes to state that it neither recognises nor contests the validity of these patents. Enquiries relative to these products for these uses should be addressed to : Mr. A. Massey, assistant secretary, Diversey (U.K.), Ltd., 42/46 Weymouth Street, London, W.1.

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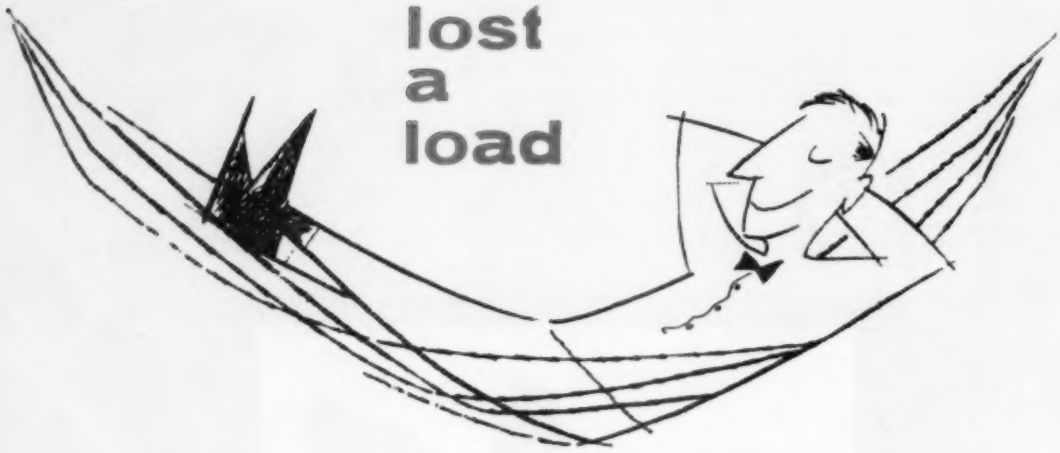

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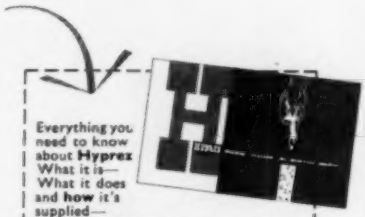

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NEWS AND ANNOUNCEMENTS

I.S.I. to Visit U.S.A. and Canada

THE council of the Iron & Steel Institute has accepted an invitation from the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) to hold a special meeting in the U.S.A. and Canada in October and November 1961. This will be only the third time that the Institute has held a meeting in America. There were meetings in New York in 1890 and 1904; plans for a meeting in 1938 had to be abandoned owing to the Munich crisis.

There will be six sections of the meeting which will extend from 17th October to 8th November. The first section, in New York, will include the opening session and a visit to Fairless Works of U.S. Steel Corporation. The meeting will then move to Niagara Falls and Canada, where visits to Atlas Steels, Ltd., Dominion Foundry and Steel Co., Ltd., Steel Company of Canada, Ltd., and Union Carbide Corporation Laboratories will feature in the programme. At this stage the party divides between Cleveland and Detroit, the programmes including visits to Republic Steel Corporation works at Cleveland, Massillon and Canton, or to the American Society of Metals Congress and Metals Exposition. Section IV, from 27th October to 2nd November, takes place in Pittsburgh, when there will be visits to U.S. Steel Corporation (Homestead Works and Monroeville Research Laboratories), Jones and Laughlin Steel Corporation (Aliquippa Works and Graham Research Laboratories), National Forge Company, Carnegie Institute of Technology, etc. The penultimate section will be in Washington and in addition to a visit to Bethlehem Steel Corporation (Sparrows Point Works) will allow sightseeing in the capital. The final section, from 6th to 8th November, will again be in New York. In addition, there will be two alternative post-meeting tours. One will be to Middletown and Chicago visiting Armco Steel Corporation, U.S. Steel Corporation (Gary and South Works), and Inland Steel Corporation. The other, a purely tourist excursion, will include Colonial Williamsburg, Richmond, Va., etc.

Mond Nickel Name Change

THE MOND NICKEL CO., LTD., an affiliate of The International Nickel Co. of Canada, Ltd., has changed its name to The International Nickel Co. (Mond), Ltd. The change of name involves no change in the company's organisation or in its business activities. The Board, in consultation with The International Nickel Co. of Canada, Ltd., the parent company, took the view that the change of name would, in addition to indicating the international nature of the company's activities, serve to identify it more closely with the Canadian company and the United States affiliate, The International Nickel Co. Inc.

Post-Graduate Welding Course

IN THE U.S.A. and in the U.S.S.R., provision for the education of welding specialists is of long standing so that the supply of qualified men far exceeds what is available in this country. It is therefore with much pleasure that the Institute of Welding is able to announce the organisation of a one-year post-graduate course in welding technology which the Ministry of Education has set up, in response to the representations of the Institute of Welding and the British Welding Research Association, at the College of Aeronautics, Cranfield.

The purpose of the course is to provide students of graduate status in either metallurgy or engineering with a specialised training to fit them for posts in the design, development and production departments of the many industries where welding is now vital. To do this, the range of subjects will be covered, with particular concentration on (*a*) the special metallurgical consideration inherent in welding; (*b*) the welding processes, their characteristics and fields of application; and (*c*) design in welding and the essential production techniques.

Already, the minimum enrolment to ensure the holding of the course has been secured as a result of promises from A.E.I. (Manchester), Ltd., British Oxygen Co., Ltd., and Whessoe, Ltd. The British Oxygen Co. has also promised to endow two bursaries for a period of seven years, the candidates to be selected by the Institute of Welding.

Waverley Gold Medal Essay Competition

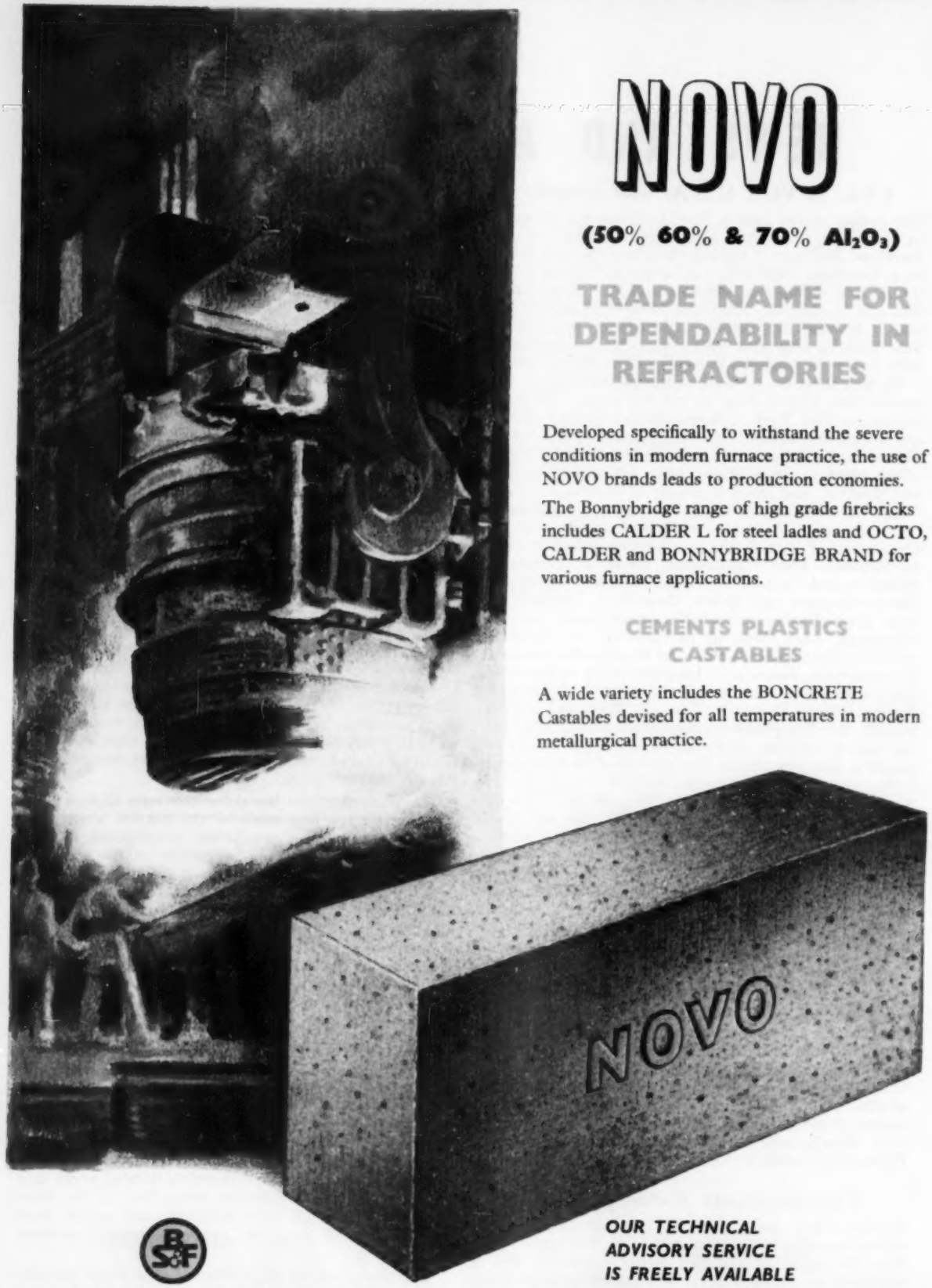
FOR the ninth year in succession, the journal *Research* is this year sponsoring the Waverley Gold Medal Essay Competition, which is designed to encourage the scientist in the laboratory and the engineer in the production plant to express his views and translate his work into an essay that will be readily understood by other scientists, directors of industrial firms, and others interested in science and technology.

The Waverley Gold Medal together with £100, will be awarded for the best essay of about 3,000 words describing a new project or practical development in pure or applied science, giving an outline of the scientific background, the experimental basis and the potential or actual application of the idea to industry or their importance to society. A second prize of £50 will be awarded and also a special prize of £50 for the best entry from a competitor under the age of 30 on 31st July 1961, which is the closing date of the competition. Entry forms and full particulars can be obtained from the Editor of *Research*, 88 Kingsway, London W.C.2.

Metallurgical Societies Co-operation

THE COUNCILS of the Iron and Steel Institute, the Institute of Metals and the Institution of Metallurgists have recently examined the problems of closer co-operation between these three societies. After careful consideration they have concluded that amalgamation of the three societies would not be practicable within the foreseeable future. The three councils therefore decided to set up a permanent joint consultative committee of the three societies which will meet regularly and advise their councils on all activities and questions of common interest.

The three councils are convinced that every qualified metallurgist should be a member both of the professional



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institution and of his appropriate scientific and technical institute, and should contribute to and influence the work of both. With this in view, the council of the Institution of Metallurgists has altered the standard subscriptions payable by members, enrolled graduates and enrolled students of the Institution resident in the United Kingdom; by agreement of the three councils, all those in the Institution of Metallurgists who pay these revised standard subscriptions will automatically have the right to apply for membership of one of the two Institutes without liability for the payment of a further membership subscription to that Insititute. It will also be possible for members of the Institutes to make one payment in respect of membership of the three bodies. The standard subscriptions referred to above are: for fellows, £9 10s.; for associates, £5 or £6 10s.; for licentiates, £2 10s. to £5; for graduates, £2 10s. to £3 15s.; and for students, £2 to £3 15s. The ranges quoted for grades other than fellow are governed by age. Full details are contained in the March 1961 issue of *The Metallurgist*, published by the Institution of Metallurgists.

Iron and Steel Institute Meeting

THE main technical sessions at the Iron and Steel Institute's annual general meeting this year will be devoted to the use of computers in the iron aud steel industry. Two new steelmaking processes—the Brymbo oxygen-electric process and the VLN process of the Steel Company of Wales—will also be discussed. This year's meeting, on Wednesday and Thursday, 3rd and 4th May, will be held at the Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1. The formal business of the meeting will be followed on the morning of 3rd May by the induction of the new president, Sir Charles Goodeve, O.B.E., F.R.S. (director, British Iron and Steel Research Association), who will deliver his presidential address. This will be followed by the discussion of the papers on the two new steelmaking processes. Neither process has been fully described before, and so this will be the first opportunity the British iron and steel industry will have to study and discuss these important new developments.

The remaining three sessions will be devoted to the use of computers in the iron and steel industry. Mr W. F. Cartwright, president of the Institute 1960-61, will open the proceedings with a general survey of the present and future rôles of the computer in iron and steelmaking, and the session on the afternoon of 3rd May will conclude with a discussion on computers in research and design, with papers from B.I.S.R.A., the Linde Co., and the United Steel Cos., Ltd. On the morning of 4th May there will be informal discussions on the use of computers for process control (in-line). Speakers from the Netherlands, the U.K., and the U.S.A. will consider the application of computers to cutting up steel products and in mill and furnace control. The final session will be on the use of computers in production control, information, etc. The subjects of the papers to be discussed include iron-ore mining, casting-bay programmes, invoicing, and production planning. Their authors are from Stewarts and Lloyds, Steel, Peech and Tozer, the Steel Company of Wales and SOLLAC (France).

An invitation is extended to all members of the British Conference on Automation and Computation (of which the Institute is a constituent society) to take part in the meeting. Further details may be obtained from the assistant secretary, the Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1.

These men are engaged in flame-cleaning the new Runcorn—Widnes bridge more than 250 ft. above the River Mersey and the Manchester Ship Canal. This bridge will replace the old transporter bridge, and before painting could be carried out it was necessary for almost all of the 5,000 tons of steel—involving an area of over 60,000 sq. yds.—to be flame-cleaned. The work has been carried out by the painting contractors, Thomas Cotton, Ltd., of Mansfield, using British Oxygen Saffire and CH equipment: the operators were specially trained by The British Oxygen Co., Ltd. Main contractors for the bridge are Dorman Long (Bridge & Engineering), Ltd.

Structural Processes in Creep

A SYMPOSIUM on "Structural Processes in Creep," organised jointly by the Iron and Steel Institute and the Institute of Metals, is being held at the Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.I., on Wednesday and Thursday, 3rd and 4th May, 1961. There will be three sessions. The first, on the afternoon of 3rd May, will be devoted to the more theoretical aspects of the subject. The morning and afternoon sessions on 4th May, will be concerned with creep in non-ferrous and ferrous metals and alloys, respectively. Papers are being contributed by the departments of metallurgy of Cambridge and Leeds Universities, University College, Swansea, and M.I.T., by the National Physical Laboratory, and by the Central Electricity Research Laboratories. Companies contributing papers, include Colvilles, Ltd., Thos. Firth and John Brown, Ltd., Hadfields, Ltd., Jessop-Saville, Ltd., the International Nickel Co. (Mond), Ltd., and the United Steel Cos., Ltd.

Participation in the symposium is open to members of the two institutes and their guests. Applications from

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non-members will be accepted, subject to the accommodation being adequate. The full programme of the symposium may be obtained from the assistant secretary, the Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1.

Induction Heating Course

THE next in the series of courses on induction heating organised by the process heating division of Pye, Ltd., will be held at the Globe Hotel, Cambridge on the 2nd and 3rd May, 1961. Admission to the course is free, and further particulars may be obtained from Mrs. E. Raeburn, Pye Process Heating, 28 James Street, Cambridge.

The Iron and Steel Institute

ELECTION OF HONORARY VICE-PRESIDENTS

AT its meeting on 16th March, 1961, the council of the Iron and Steel Institute elected as honorary vice-presidents, DR. HOWARD BIERS, senior consultant, The Union Carbide International Co., and DR. T. P. COLCLOUGH, C.B.E., technical adviser, British Iron and Steel Federation.

AWARD OF MEDALS AND PRIZES

The council of the Institute has announced the award of the following medals and prizes :

Bessemer Gold Medal for 1961—To MR. W. BARR, O.B.E., director and chief metallurgist, Colvilles, Ltd.

Sir Robert Hadfield Medal for 1961—To MR. E. DAVIES, managing director, Brymbo Steel Works, Ltd.

Williams' Prizes for 1960 (£50 *each*)—To MR. T. MCHUGH and MR. F. A. KIRK (Low Moor Fine Steels, Ltd.) for the paper "Some Aspects of Steel Extrusion" (their co-author, Mr. R. Cox, was not eligible for an award); and to MR. J. CHAPMAN (Steel, Peech & Tozer), and MR. W. MONTGOMERY (Round Oak Steel Works, Ltd.), for the paper "The Effect of Flow Distribution on Air Preheat in the Open-Hearth Furnace."

The medals and prizes will be presented at the annual general meeting, to be held on Wednesday, 3rd May, 1961, at the Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

The Morgan Crucible Co., Ltd.

AS FROM 1st April, 1961, the Morgan Crucible Co., Ltd., ceased to trade and became a holding company, the crucible department of the company becoming a wholly-owned subsidiary known as Morganite Crucible, Ltd, whose address is Norton Works, Woodbury Lane, Norton, Worcester. Tel: Worcester 26691. Telex: 33191.

Albright & Wilson Agreement

ALBRIGHT & WILSON (MFG.), LTD., have concluded an agreement with Hanson-Van Winkle-Munning of Matawan, New Jersey, a company long established in the U.S. metal finishing industry, whereby Albright & Wilson will be able to call on wide American experience in the design of automatic plant for electroplating, chemical polishing and anodising. This represents a considerable extension to the existing range of plant which the company provides to operate its specialist metal finishing processes, notably Phosbrite chemical polishing solutions and Plusbrite addition for nickel and silver plating.

Industrial Finishes Exhibition

THE INDUSTRIAL FINISHES EXHIBITION to be held at Earls Court, London, from 8th to 11th May, 1961, will have, as an additional attractive feature, a convention at which papers covering such aspects of metal finishing as automatic polishing, surface coating methods and equipment, nickel-chromium plating, organic coatings, finishing aluminium, metal spraying, titanium in industrial finishing, etc., will be presented.

Delegates will be entitled to participate in the programme of films and works visits, as well as attending all sessions of the convention and taking part in the discussions. Registrations should be made with the Convention Secretary, Scientific Surveys, Ltd., 97 Old Brompton Road, London, S.W.7. Fees are one guinea, or three guineas including printed papers.

Personal News

THE council of the Institute of Marine Engineers have great pleasure in announcing that HIS ROYAL HIGHNESS THE PRINCE PHILIP, K.G., has honoured the Institute by accepting their invitation to become president for 1962/63.

MR. D. L. CAMPBELL has resigned from the board of Campbell, Gifford & Morton, Ltd., consulting engineers, on his appointment as managing director of Davy-Ashmore Export Co., Ltd.

MR. J. W. HAIG-FERGUSON has recently been appointed managing director of R. & J. Beck, Ltd., one of the Griffin & George group of companies, and manufacturers of optical instruments.

MR. R. F. HAMMAN has joined the Manchester sales office of West Instrument, Ltd., the temperature control specialists, and MR. B. FRANCIS and MR. R. WHITE have taken up appointments in the engineering department at Brighton.

THE council of the Institution of Mechanical Engineers has accepted with regret the resignation of MR. B. G. ROBBINS, who has been secretary for the past ten years. He is succeeded by MR. K. H. PLATT, M.B.E., who joined the Institution staff in 1952, becoming assistant secretary in 1953 and deputy secretary in 1956.

IT is announced by AEI (Rugby), Ltd., that MR. E. T. MUSTON is appointed general superintendent, Rugby Works: since 1949 he has been superintendent of the fabrication factory.

BRIGHTSIDE ENGINEERING HOLDINGS, LTD., announce the appointment of MR. J. S. LEIGH as assistant secretary of the company, and as secretary of The Brightside Foundry & Engineering Co., Ltd.

MR. R. SMITH, who has been chairman of Stein & Atkinson, Ltd., for ten years, has now retired, and MR. H. W. HOWES has been appointed chairman in his place. Mr. Howes has been a director of Stein & Atkinson, Ltd., for the last eleven years.

Two important appointments are announced by Associa-

ted Electrical Industries, Ltd. MR. D. EDMUNDSON, general manager (Rugby works), since January 1960, is appointed manufacturing manager (AEI electronic apparatus division) to fill the position previously occupied by the late MR. E. T. W. BARNES; and MR. G. P. THOMPSON, until recently manager (manufacturing), at Rugby, becomes manager (Rugby works).

MR. R. P. NEWMAN has been appointed head of the members' service department of the British Welding Research Association in succession to MR. P. H. R. LANE, who has been appointed director of research of the Drop Forging Research Association. MR. T. R. GURNEY succeeds Mr. Newman in charge of fatigue researches at B.W.R.A.

DR. R. V. M. PERRIN, of Paris, noted Ugine authority; MR. C. E. REISTLE, JR., of Houston, Texas, executive vice-president of Humble Oil & Refining Co., and a former A.I.M.E. president; and DR. J. F. THOMPSON, of New York, honorary chairman of The International Nickel Co. of Canada, Ltd., and of its United States subsidiary, The International Nickel Co., Inc., have been elected to honorary membership of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

MR. G. A. HART, of Montreal, president and chief executive officer of the Bank of Montreal, has been elected a director of The International Nickel Co. of Canada, Ltd. Mr. Hart fills the vacancy on the board caused by the recent death of MR. E. G. BAKER, chairman of The Canada Life Assurance Co.

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION has pleasure in announcing that MR. H. F. SPENCER, managing director of Richard Thomas & Baldwins, Ltd., has accepted appointment as president of the Association, in succession to the late Sir Charles Bruce-Gardner.

MR. J. OLDROYD, T.D., has been appointed general manager of the Lead Development Association. He has resigned from his present position of secretary of the British Electrical & Allied Manufacturers' Association to take up his new work in April.

MR. P. LAMBERT, has been appointed head of the engineering section of the British Steel Castings Research Association, Sheffield. Mr. Lambert, joined the Association's staff in September, 1955, as a senior investigator in the plant engineering section.

THE council of the recently formed Drop Forging Research Association has appointed MR. P. H. R. LANE to be the first director of research. For the past twelve years Mr. Lane has been with the British Welding Research Association where he was head of the members' service department.

STONE MARINE ENGINEERING CO., LTD., announce that they have taken over the sale of all yellow and white-metal products previously handled by J. Stone and Co. (Propellors), Ltd. MR. P. A. T. BURROWS has been appointed sales representative for these products.

MR. J. C. PIPKIN was appointed to the board of directors of the Thermal Syndicate, Ltd. In addition to his new duties as a director he will continue in his capacity as company secretary.

FOLLOWING the resignation of MR. D. B. GOODCHILD, London area sales representative of Sanderson Brothers and Newbould, Ltd., MR. R. A. SWARBRICK has been transferred to London from the Manchester area.

WICKMAN, LTD., announce that MR. H. B. MORRIS, secretary, has been appointed to the board of the company.

FOLLOWING the resignation of MR. D. McL. BURNELL, MR. T. K. SINGER has been appointed general sales manager of James Booth Aluminium, Ltd. He was formerly an executive with Kaiser Aluminium and Chemical Corporation and has represented that company both in the U.S.A. and in this country. MR. F. J. MILLS continues as sales manager of James Booth.

MR. L. DENISON has joined the staff of the Castrol group as technical consultant on industrial oils to the group's associate company in Brazil, Castrol (Lubrificantes) S.A.

MR. R. G. HOOKER, J.P., has been appointed deputy managing director of K and L Steelfounders and Engineers, Ltd., Letchworth. Mr. Hooker was formerly general manager of Brush Electrical Engineering Co., Ltd.

DR. W. S. WALKER, who has been mainly concerned during the last ten years with reorganising and largely rebuilding the Round Oak Steel Works, resigning at the end of 1960, has joined Campbell, Gifford and Morton, Ltd., the consulting engineers, of 52 Queens Road, Weybridge.

MR. J. E. C. BAILEY, C.B.E., managing director of Baird and Tatlock (London), Ltd., Hopkin and Williams, Ltd., and W. B. Nicolson (Scientific Instruments), Ltd., recently made a tour of the companies' branches and agents in Africa.

MR. A. D. LIDDERDALE has been appointed general manager of Leybold-Elliott, Ltd., the new company recently formed by Elliott Brothers (London), Ltd.—a member of the Elliott-Automation Group—and Leybold's of Cologne.

MR. J. H. PATCHETT has retired from the board of Dorman Long (Steel), Ltd., and from executive duties: he will continue to be available as a consultant to the company. MR. G. FOSTER, a special director, has been appointed general manager (production) and MR. F. KENNEDY and MR. C. MOODY, general works superintendents.

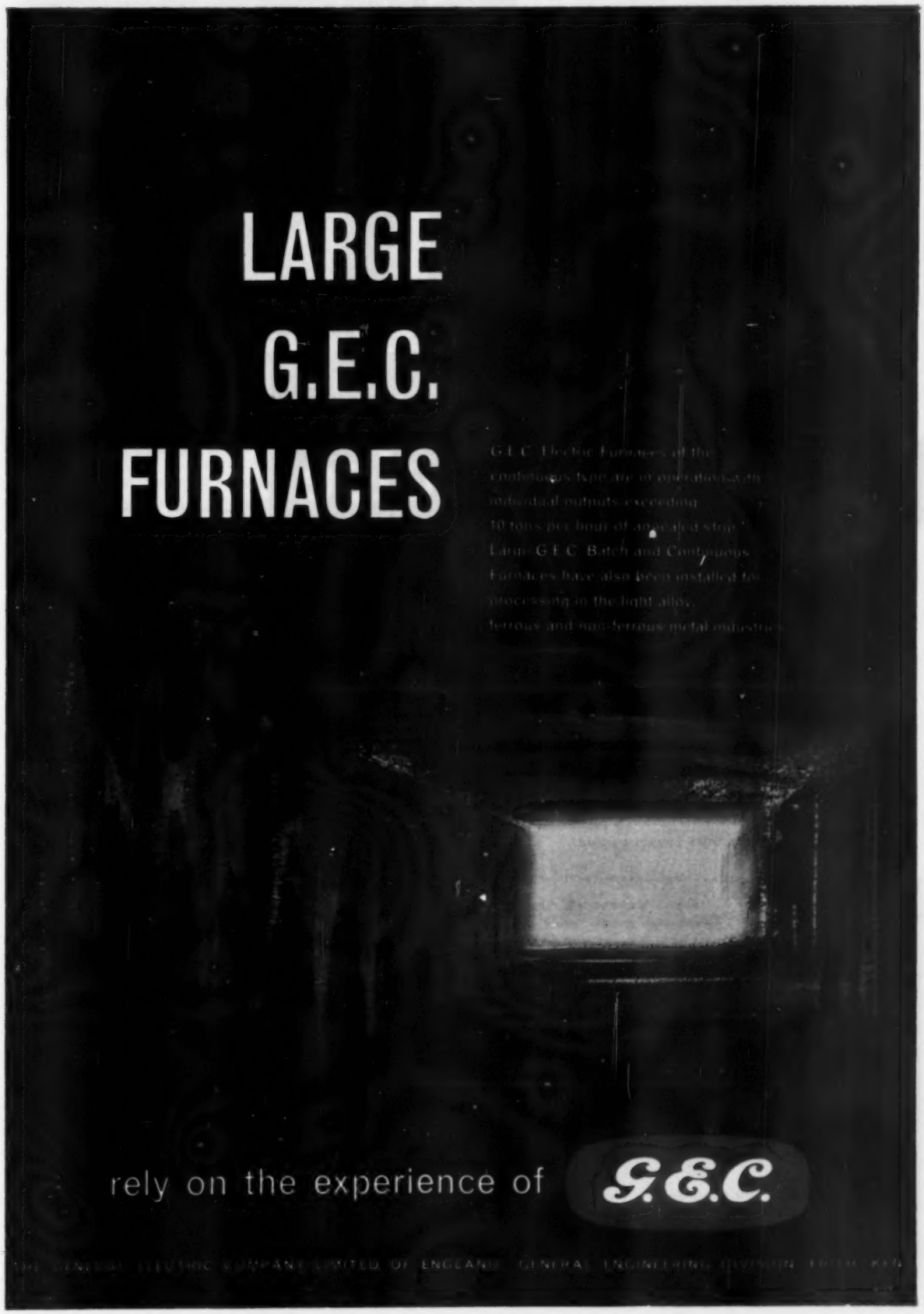
MR. J. BISHOP, formerly with A. J. Mare (B'ham), Ltd., has joined the staff of The Electronic and Mechanical Engineering Co., Ltd., Halesowen, near Birmingham, and will be responsible for technical sales of the company's existing range of creep testing machines, together with design and development of other electronic systems to customers' specification.

HAVING reached normal retirement age, MR. A. E. REDDELL, O.B.E., has retired from the board of directors of Vickers-Armstrongs (Engineers), Ltd., and from his office of director-in-charge of the Weymouth works of that company.

MR. D. L. CAMPBELL, M.C., has been appointed managing director of Davy-Ashmore Export Co., Ltd., the newly-formed subsidiary of Davy-Ashmore, Ltd.

MR. J. BLACK, deputy chairman of Metal Industries Ltd., has been appointed, in addition, managing director, and MR. W. PADLEY deputy managing director.

MR. E. V. DEWHIRST, chief metallurgist of Specialloid, Ltd., has recently been awarded the Insignia Award of the City and Guilds of London Institute for his thesis on "The Surface Treatment of Piston and Liner Assemblies for Internal Combustion Engines."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rely on the experience of
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two outstanding electronic instruments by KENT, from which to - - -

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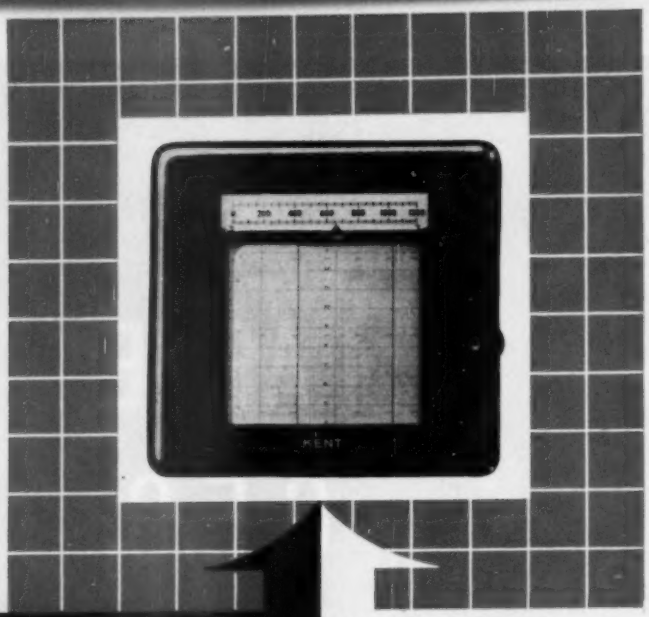
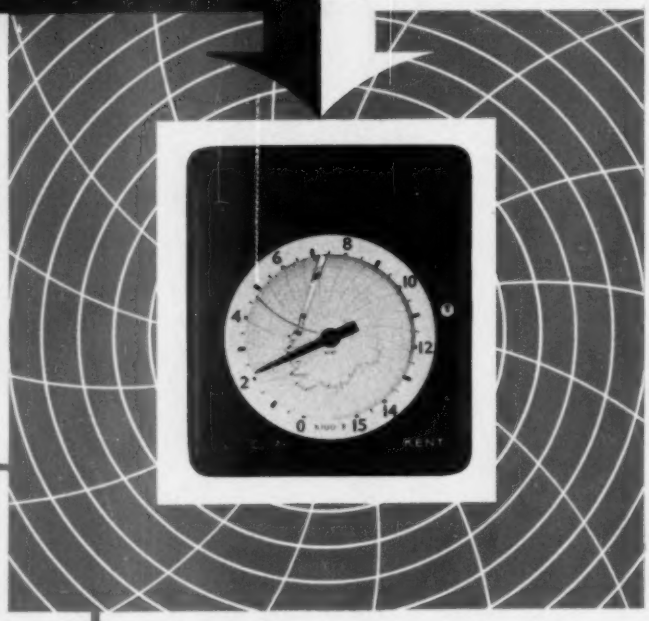


"Mark 3" indicator-recorder

"Commander KE" indicator-recorder



Both these modern high-speed indicator-recorders offer every user-advantage: plug-in modular construction, maximum accessibility, minimum maintenance etc. Both are available also as automatic controllers. Common electronic systems are employed, and the KENT series of amplifiers provides for a wide range of input conditions in temperature (thermocouple etc.), millivoltage, oxygen-percentage and electrolytic-conductivity measurement. The **Mark 3**—strip-chart recording—is available in up to 16-point form, depending on application. Both instrument types, in potentiometric version, incorporate the latest Zener-diode reference unit, which dispenses with standard cell etc.

Write or telephone (Luton 2440) for descriptive literature today.

"Type 3" Reference Unit

An extremely accurate constant-voltage source providing the necessary highly stable d.c. supply for the instrument measuring circuit

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RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Low-Temperature Joining of Aluminium

AUTOCHEMIC* 990 is a specially formulated paste compound, and is the latest product of the Eutectic Welding Alloys Company's international research centres. It is claimed that this chemically complex compound gives high strength, corrosion resistant joints on virtually all types of aluminium and aluminium alloys and requires no finishing or after-treatment. No filler alloy is required : the compound is merely painted on where required facilitating preplacement on multiple or production joining applications, and giving great economy in use. 990 is recommended for all fine work such as wire and cable joining, instrument parts, cans, small wave guides, floats and other small fabrications. A neat fillet easily cleaned in warm water is produced by applying the compound and heating indirectly. A series of chain-type reactions take place terminating in metallic reduction at the reaction temperature of 400° C.

Eutectic Welding Alloys Co., Ltd., North Feltham Trading Estate, Faggs Road, Feltham, Middlesex.

The Fluroprint

THE Hilger and Watts Fluroprint is a new fully automatic X-ray fluorescence spectrometer. It has been developed to analyse materials rapidly in a flexible routine. Particular aims in designing the instrument were ease in changing from one analytical programme to another, high accuracy and sensitivity, and simplicity and reliability in operation.

The Fluroprint will deal with any element having an atomic number of 12 (magnesium) or higher, and will analyse up to twenty elements in one operation. The instrument scans through the spectrum, and is programmed to stop at the appropriate angle for each element. The spectrometer is completely evacuated. The Fluroprint works on a ratio system, and pulses are counted during the accumulation of a pre-set number of counts on the monitor. Scintillation and flow proportional counters are arranged to cover the whole range of an analysis, and no adjustment is needed. To change from one type of analysis to another it is only necessary to pull out the plug-board and substitute another covering the required programme. An electric typewriter automatically prints the results obtained from the line intensities, and interpretation is rapid and straightforward.

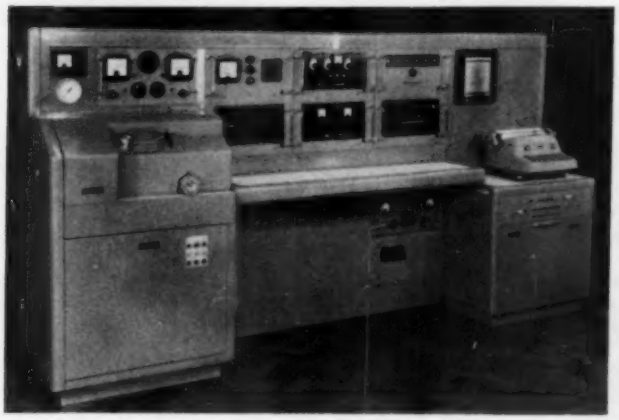
Hilger and Watts, Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.

Vacuum Tempering Furnace

A VACUUM-PURGE controlled-atmosphere tempering furnace with a work space 10 in. in diameter and 14 in. deep ; operating pressure to 50 microns Hg ; input of 9 kW ; and maximum operating temperature of 1,500° F. (815° C.) is announced by Ipsen Industries, Inc. This unit completes a line of Ipsen vacuum heat treatment equipment permitting treatments from 200° F. to 4,000° F. (90° C. to 2,200° C.) in vacuum or atmosphere. The new unit (series VVD–10 × 14), is designed primarily to bright temper work previously heat treated in the VVFC–10 × 14, so that work does not have to be removed from the basket. It can also be used for annealing ferrous and non-ferrous materials and precipitation hardening beryllium copper, etc. Minimum floor space is required for the VVD–10 × 14. The furnace and vacuum system are housed in a single unit having a floor area of 42 in. × 48 in., and the separate control panel with strip chart temperature recorder is 6 ft. high and occupies an area 24 in. × 13 in.

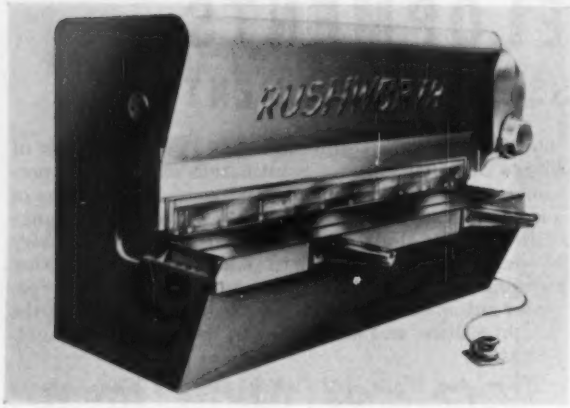
The cylindrical work chamber has steel basket guides

* Regd. Trade Mark



The Hilger and Watts Fluroprint

Ipsen vacuum tempering furnace : series VVD—10 × 14.



The Rushworth precision guillotine shearing machine.

and supports, and the 10 in. diameter by 14 in. deep alloy work basket is charged vertically. A circulating fan is located inside the cover of the vacuum furnace and is direct-connected to a ½ h.p. motor mounted on the cover. After vacuum purging and back-filling, the work is heated by 100% forced convection. The fan forces the gas to the walls, down past the heating coils and up through the work: the unit has three 3 kW. Iconel sheathed heaters for a total input of 9 kW. The hinged cover is operated and sealed by two airdraulic cylinders, which permits tight sealing under all pressure conditions. The vacuum system consists of a 35 cu. ft./min two-stage rotary-piston mechanical pump, belt driven by a 2 h.p. motor.

The unit works with any gas, whether reducing, oxidising, or inert, and internal water cooling coils and directional baffles permit rapid cooling of the circulating gas. The unit can be safely operated under partial pressures or full pressure with such gases as hydrogen, "endothermic," cracked ammonia, or "rich endothermic." Operating advantages of the vacuum furnace include the prevention of surface oxidation, the ability to produce bright work, the prevention of surface contamination, and the prevention of gas absorption after vacuum heat treatment.

Ipsen Industries, Inc., 53 Victoria Road, Surbiton, Surrey.

Guillotine Shear

WITH a view to providing a range of precision guillotine shearing machines suitable for high speed production methods, Rushworth & Co. (Sowerby Bridge), Ltd., have designed a new machine known as Series 25. This unit, built entirely of fabricated steel, is characterised by its extremely rigid construction which affords maximum resistance to deflection.

The machines produces a very clean sheared edge by virtue of the fact that the slide moves downwards and backwards simultaneously on the downward stroke as the slideways have a two-degree forward slope. The high quality alloy steel blades have four cutting edges, and the bottom blade is mounted on a blade block which is adjustable over its full length to permit accurate setting of the blade clearance. An electric motor with high slip characteristics is mounted co-axially with the worm shaft and fly-wheel, and the drive is transmitted through a multi-jaw dog type clutch which is released by means of a solenoid-operated plunger. This is controlled by a foot switch at the end of a flexible armoured cable, a feature which is particularly useful when dealing with large plates, but alternative controls such as push buttons mounted on the machine or on a pendant can be fitted, if preferred.

The standard hold-down is of the plunger type, mechanically operated, each plunger being individually spring-loaded. A hydraulic system with plungers operated from a master cylinder can be supplied as an alternative if required. Two support arms are fitted to the front of the table and a squaring arm with two swing stops in a length to suit the particular application can be provided. A precision back gauge with direct-reading dial indicators can be fitted in place of the standard back gauge. This can be power-driven, operated by push buttons on the front of the machine, with a dial indicator mounted near the push buttons giving a direct reading of the position of the gauge bar.

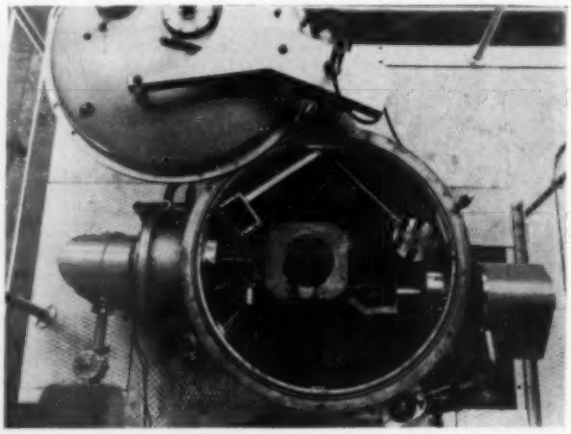
Lighting is provided behind the front guard to shine on the shearing area, with, if necessary, a wire arranged to throw a shadow on the exact cutting line. A waste chute of a length suitable for the operating requirements is fitted to push cut-off blanks away from the machine. Maintenance is simple as lubrication to all plain bearings and wearing surfaces is by a one-shot system. The worm and worm-wheel run in an oil bath.

The Rushworth Series 25 precision guillotines are supplied in models with a mild steel capacity ranging from 6 ft. × ¼ in. to 12 ft. × ¼ in. Speed of operation is 60 strokes per minute.

Rushworth & Co., (Sowerby Bridge), Ltd., Sowerby Bridge, Yorkshire.

Vacuum Induction Melting

As a result of recent development work, the Edwards High Vacuum medium size induction furnace is now available with a coil assembly of 100 lb. steel capacity, which is fully interchangeable with the 56 lb. coil which has hitherto been the nominal capacity. The melting capacity of the furnace may now be altered by the use of



The 100 lb. capacity coil assembly can be seen in this view of an Edwards High Vacuum induction melting furnace.

either a 28, 56 or 100 lb. coil assembly, all of which are fully interchangeable.

The assembly lip tilts for pouring from a rotating co-axial seal carrying the power and water supplies to the coil. The furnace assembly is contained within a vertical water-cooled vacuum chamber which incorporates charge addition mechanisms, immersion pyrometers, a bridge breaking mechanism, internal light and a support platform for the ingot mould. The chamber interior is viewed through a window fitted with a wiper and radiation shield attachment which keep the window substantially free of metal deposits. The charging mechanisms enable one-third of the bulk charge and a random choice of six alloying additions to be added to the melt without breaking the vacuum. Accurate temperature measurement up to 1,800° C. is obtained by means of two immersion pyrometers. Another new feature of the furnace is the lid " lift and slew " mechanism which is hydraulically operated by means of a hand pump on the furnace platform. This is now a standard fitting which obviates the need for an overhead hoist for lifting the lid.

The standard furnace is fitted with a high capacity vapour booster pump designed specifically for vacuum processes where large quantities of gas are evolved and low ultimate pressures are required in minimum time. The illustration shows a furnace installed at Messrs. Sanderson Brothers & Newbould, Ltd., of Sheffield who, as part of their widespread activities in the steel industry, carry out high quality vacuum melting for the trade and their own purposes. The 100 lb. capacity coil assembly and new lid lifting mechanism can be clearly seen.

Edwards High Vacuum, Ltd., Crawley, Sussex.

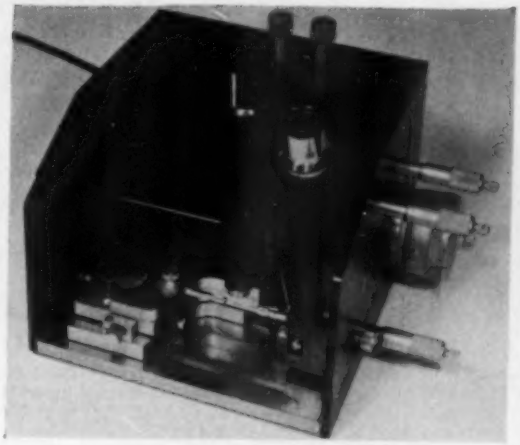
Lightweight Cutting Blowpipe

THE FIREFLY, British Oxygen's new ultra-lightweight hand cutting blowpipe, which was previewed at the 1960 Motor Show as the perfect partner for the Saffire lightweight welding blowpipe, is now generally available. It weighs only 12 oz. and can cut mild steel up to ¾ in. thick. Initially, nozzles will be available for use with acetylene, but the early introduction of a range of propane nozzles is also planned. The blowpipe and its accessories are supplied in a plastic carrying case. The new blowpipe is designed on the latest nozzle mixing principles; the gases are fed to the nozzle through separate supply tubes so that gas is safe and resistant to backfires. Fitted with forward-mounted trimming valves which ensure perfect flame control the Firefly is a robust, light and compact hand cutter, ideal for repair work and delicate cutting of light sheet steel.

The British Oxygen Co., Ltd., Bridgewater House, St. James's London, S.W.1.

Micro-Tensile Testing Machine

THE micro-tensile testing machine made and marketed by Techne (Cambridge), Ltd., was developed in the Research Laboratories of Tube Investments, Ltd., at Hinxton Hall, near Cambridge, for testing single crystal whiskers which are often too small to resolve with the naked eye, but is suitable for any small specimens of similar dimensions. It employs a torsion balance to apply loads between 1 mg. and 400 g. to specimens having lengths down to 0·5 mm. and cross-sectional



The Techne micro-tensile testing machine.

areas between 10^{-2} and 10^{-7} sq. min. Extensions from a few Ångström units to 15 mm. are detected by an autocollimating telescope/mirror system and are measured by a sensitive micrometer acting through a simple lever train. In normal tests extension measurements to the nearest 100 Å are adequate, but in certain circumstances readings have proved repeatable to a standard deviation of less than 5 Å (1/50 millionth of an inch). The stability required to measure such quantities is achieved by the extensive use of carefully designed flexure pivots.

The machine is inherently drift-free as it is wholly mechanical and optical in design, and it may readily be adapted for tests in compression, for tests in special atmospheres, and for thin film testing. It is wholly self contained in a small box, which can stand on any table.

Techne (Cambridge), Ltd., Duxford, Cambridge.

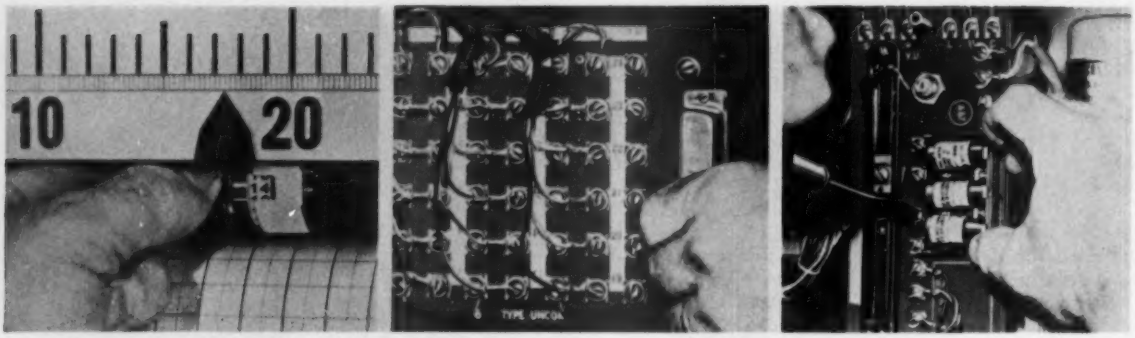
High-Purity Mercury

JOHNSON MATTHEY announce that, following the installation of new equipment, they are now able to offer in quantity two grades of mercury for laboratory and industrial use. Redistilled mercury has a maximum impurity content of 5 parts per million (mostly copper and silver), and triple-distilled mercury a maximum of 1 part per million. Every batch is examined spectrographically to ensure that the limits are not exceeded. The metal is supplied in 7, 14, or 28 lb. containers, though other packings can be provided. The product is described in a newly issued data sheet in the Electrical Engineering series, 1300 : 492

Johnson, Matthey & Co., Ltd., 73-83 Hatton Garden, London, E.C.1

Universal Multi-Point Recorder

A NEW version of the multi-point electronic strip chart recorder to enable alternatives of 2, 3, 4, 6, 8, 10, 12, 16, 20 or 24 points to be measured and recorded on one instrument, is announced by Honeywell Controls, Ltd. Known as the Universal Electronik multi-point recorder, it increases the scope of recording different numbers of



To change the number of points to be recorded by the Honeywell Universal instrument, change print wheel-cum-indicator (left); and replace shorting plug unit on special input terminal board (centre). To alter the range, slip in new range resistor card (right).

variables on the same instrument. Range and compensation can also be altered. Research and test departments in many industries are likely to be the most interested in this new development, although the Universal is by no means limited to these fields.

Variation is simply obtained, in a matter of seconds. The action consists of replacing the print wheel-cum-indicator dial which is fixed by a thumb-tight nut; then replacing a shorting plug unit on a special input terminal board inside the instrument. The range of the instrument can also be changed by slipping in new range resistor cards, and compensated for different types of measuring unit by slipping in a new input terminal board.

The Universal design can be supplied on any of the Honeywell non-control strip-chart recorders, thus providing an economical instrument for research work or process applications where the numbers of records being monitored changes frequently.

Honeywell Controls, Ltd., Greenford, Middlesex.

Strippable Plastic Coating

PROMEX is a complementary product to Croda's Crocell range of thick-film hot-dip strippable plastic coatings for anti-corrosion protection. Crocell is a non-inflammable plastic-based rubber-like anti-corrosive preparation whose main advantages are: ease of application; ease of removal; economy in use; reduction in packing costs; and security of the protected article against corrosion and abrasion. The coating is transparent, thus allowing identification marks to be read through it, and when necessary the film can be removed by slitting and peeling off, leaving a thin film of anti-corrosive mineral oil. This material is available in various grades: GP.1 to Ministry of Aviation specification CS. 2486; GP.2 for general use; GP.8 where an especially light-coloured material is required; and GP. 2422 for use as a stopping-off coating in electroplating.

Crocell is supplied in briquettes which are melted in indirectly heated containers, the coating being applied by dipping into a bath maintained at 150–180° C. In some instances it is not possible to dip items, particularly large ones, into thick-film coatings in heated baths; nor are thick films always desired. Such items can now be dipped in cold liquid Promex and allowed to dry, when it will be found to be covered with a tough elastic skin, sufficiently adherent to the metal surface to "stay put," but easily removable by peeling. The standard formulation is clear, but it can be pigmented with aluminium powder, or dyed green, red or blue. It is applicable by brushing, spraying or dipping.

Croda, Ltd., Cowick Hall, Snaith, Goole, Yorkshire.

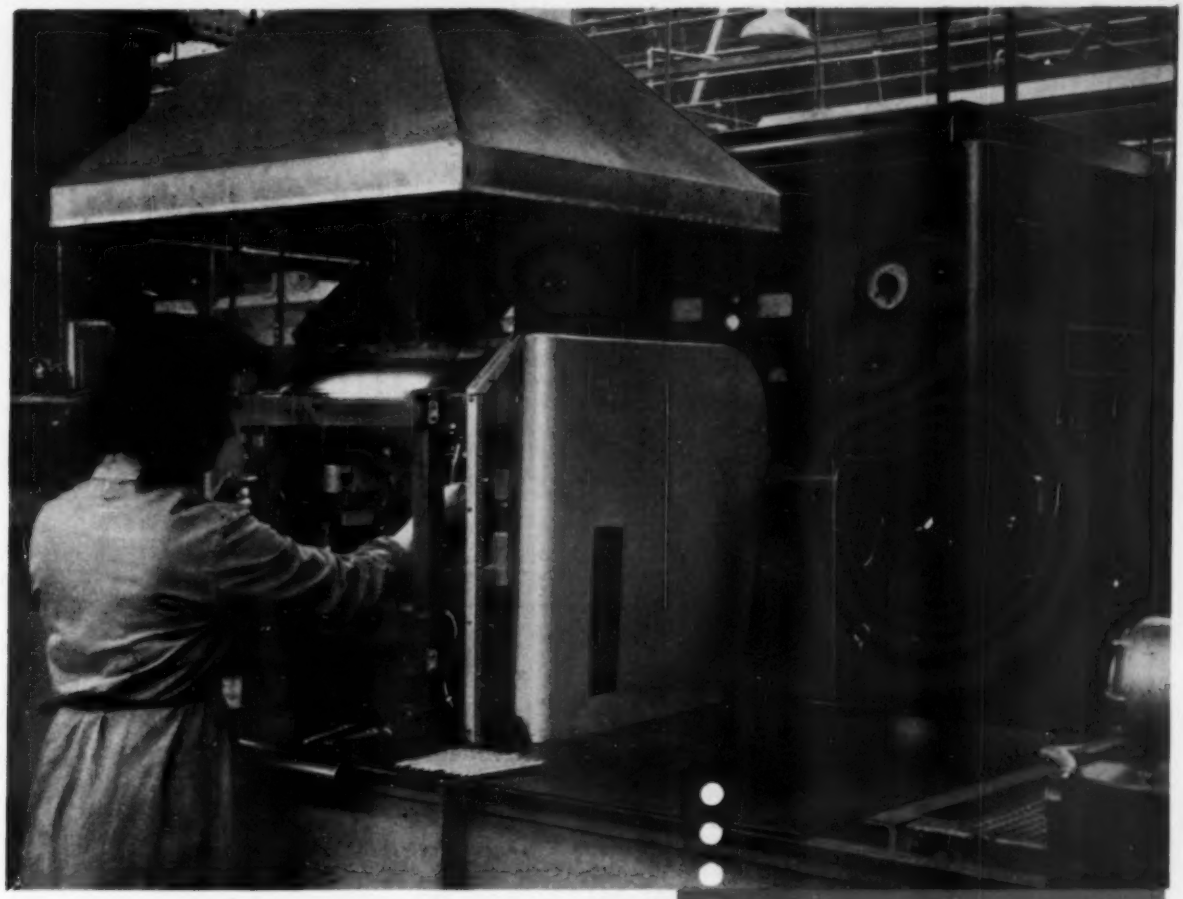
Recording Flue Dust Monitor

IN view of the recent litigation due to the damage caused by the outfall of oil smuts from industrial chimneys, the new EEL recording flue dust monitor goes into standard production at an opportune moment. This apparatus is designed to record automatically the emission of harmful dust, grit and oil particles from industrial boiler house chimneys and to give immediate warning to the engineer in charge, of the offensive nature of the smoke plume before it leaves the main stack. Not only does this photoelectric apparatus prevent damage and offence to surrounding property, but also gives warning of the inefficiency of solid fuel pulverisation, dust collecting plant, oil firing apparatus and the fuel in question.

The monitor consists of a sampling and measuring head, a control unit, and a recorder unit. The sampling and measuring head is fitted to a duct leading to the chimney and samples the percentage of course dust and grit photoelectrically (with progressive emphasis from 20 microns upwards), at predetermined intervals, usually of 15 minutes. If the dust burden reaches offensive proportions the signals passed to the control unit will automatically actuate an alarm system. Should the burden become so great as to be incapable of being recorded at normal set intervals, the instrument automatically records more frequently. The recorder unit provides pen readings graphically on a 24 hour chart. The chart presents these readings in units of percentage obscuration/minute relative to a vertical surface exposed to the dust.

This new technique offers advantages over other systems in that it detects grit and oil smuts which would be undetected until complaints had been received from outside sources. The instrument has been developed in conjunction with the Central Electricity Generating Board's Research Laboratories.

Evans Electroselenium, Ltd., St. Andrew's Works, Halstead, Essex.



Wild-Barfield A.H.F. equipment is used by Wolf Electric Tools, Ltd., (manufacturers of the well-known Wolfcub drills etc.), for the hardening and tempering of small gears, shafts and pinions. Many other industrial concerns have found that Wild-Barfield A.H.F. induction heating speeds production, saves space and offers savings all along the line. Our engineers will be glad to supply further details and explain how Wild-Barfield A.H.F. equipment can help you.

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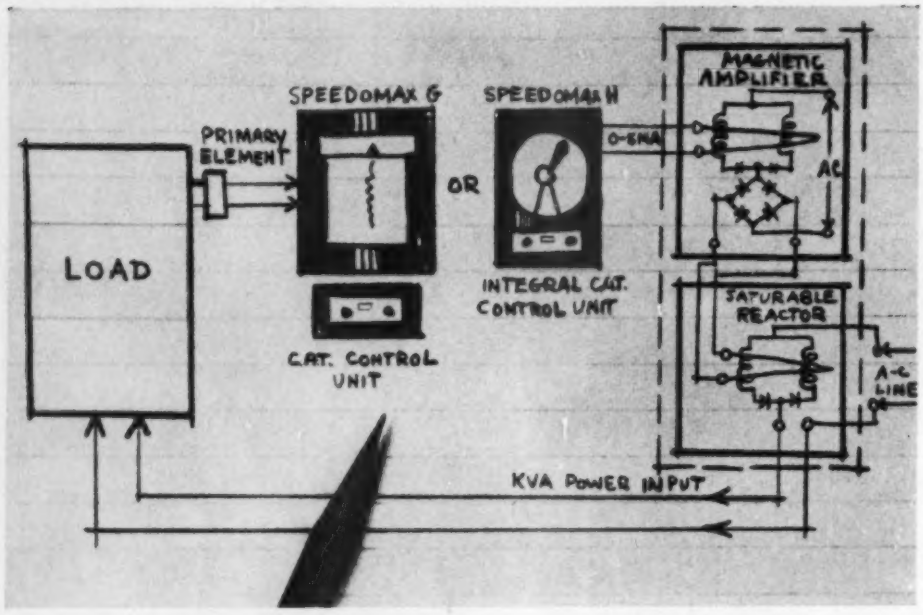

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CURRENT LITERATURE

Book Notice

AN ATLAS OF PROCESS DEFECTS: PLATING ZINC ALLOY DIE CASTINGS

Development Report No. 64, 28 pp., published by The British Non-Ferrous Metals Research Association, Euston Street, London, N.W.1. 15s.

FREQUENTLY, electroplaters experience more rejects in plating zinc alloy die castings than with other materials, e.g. steel and brass. To some extent this is due to the greater variability of castings compared with rolled material, and some of the troubles that platers experience are no doubt due to minor defects in the die castings. However, defective die castings are by no means the only source of plating rejects, and a survey of over a thousand rejected plated castings has shown that the troubles are very often associated with the preparation of the die castings for plating and the plating process itself. In the course of the examination of this large number of rejected articles, most of the common causes of process defects have been encountered, and the more important of these are described in this atlas of defects, which includes suggestions for their elimination.

Three types of blistering, five types of pitting and several other defects are included. The distinction by visual examination between the various forms of pitting is fairly clear, but not so clear with the three types of blistering. Nevertheless, generally speaking, the examination of a number of defective castings with the aid of a small hand lens will enable them to be placed as a group in one of the categories and so the most likely cause of the trouble established. For this reason the illustration in the book—dealing with more than a dozen types of defect—are all at about × 8 magnification, showing the surface appearance of the defects as they would be seen through a hand lens.

The defects illustrated in this atlas are confined to those arising during plating: those developing in service are excluded.

Trade Publications

A NEW leaflet on the application of heat resistant coatings by the metal spraying process has recently been issued by Metallisation, Ltd. It deals with aluminium coatings, aluminised coatings (involving heat treatment after spraying), and nickel-chromium coatings, and refers also to a modification of the aluminising process for the treatment of steel exposed to molten metals.

FOUR catalogues dealing with the complete range of Keith Blackman Tornado standard blowers and exhausters are now available. Cast iron blowers and exhausters, directly or indirectly driven, are featured in publications Nos. 7, 53, and 54, which deal, respectively, with Type N units with a volume range of 30 to 275 c.f.m. at pressures from 6 to 14·5 in. w.g.s.p.; Type MP units with a volume range of 20 to 3,000 c.f.m. at 1·0 to 9·0 in. w.g.s.p.; and Types 7, 8 and 9 with a volume range (according to whether 1, 2, or 3 stages) of 100 to 1,250 c.f.m. at 9 to 52 in. w.g.s.p. Publication No. 47 deals with backward-bladed Types 8, 9, 13 and 14 steel plate blowers and exhausters, directly or indirectly driven, with a volume range of 200 to 10,000 c.f.m. at 4 to 30 in. w.g.s.p. A further new publication, No. 55, describes the Tornado hydro precipator dust collector, a wet collector available in sizes to handle volumes of fine-dust-laden air or other gases from 1,000 to 40,000 c.f.m.

THE development of heat resisting alloys and their fabrication is a continuing process, and a leaflet dealing with the Nimonic alloys in sheet form is available from Henry Wiggin & Co., Ltd. Details are given of the tensile and stress-rupture properties of various alloys in the series after argon-arc welding.

THE efficiency of cleaning and finishing processes applied to metal articles can be enormously affected by the addition of small amounts of certain organic chemicals, while other such chemicals can be used in large amounts particularly for de-rusting and electroplating. The Geigy Co., Ltd., produces a range of both these types of chemicals, many of which are still at the development stage, and the very wide scope of uses is still being explored. In a publication entitled "Chemicals for Metal Treatment," the company's development division gives brief particulars of the various compounds concerned, complete with an index based on applications.

THE 1961 Industrial X-ray Catalogue issued by Kodak Ltd., provides, in easy-reference form, information about the salient features, sizes, prices and stock availability of Kodak industrial X-ray materials and equipment. These include sensitised materials, chemicals, and exposure, processing and viewing equipment.

WE have received from Enfield Rolling Mills Ltd., a copy of the new brochure on E.R.M. Resistance Welding Electrode Materials. These are the products of a special division concerned with high strength, high conductivity copper alloys, such as are needed for making new equipment and as spares for working machines in this field. They are available in the form of drawn bar and rod. forgings and stampings, castings, copper tungsten products, spot welding electrodes, seam welding electrode wheels, and electrode holders and a laptors. In addition, copper and copper alloy machined components are produced to customers' drawings. Typical physical properties and the principal uses of these alloys are given in tabular form, together with dimensional details of standard electrodes, irons and adaptors.

DESIGNED to extend the popular range of milling equipment produced by Samuel Osborn & Co., Ltd., the Titanic facing chuck has all the advantages of screw thread drive combined with a quick release mechanism and a foolproof safety device. This new development is featured on leaflet No. 22, together with details of Osborn mills available for use with this chuck.

BEARING the title "Oxygen is not just for Breathing," the principal article in *Torch*, No. 24, the quarterly technical bulletin issued by British Oxygen, presents a brief survey of the discovery of oxygen and the developments of a new industry. Other features deal with a little-known maintenance operation that keeps London's

underground traffic moving, the adaptation of the Saffire blowpipe for automatic operation, an unusual powder cutting job, and the growing application of propane in industry.

THE INCANDESCENT HEAT CO., LTD., have recently issued a leaflet which takes the form of a reprint of a short article on a process developed by the company's gas atmospheres division for producing a nitrogen/hydrogen mixture from blast furnace gas. The gas, referred to as HNX or Hy-Nitrogen, is finding increasing use in the heat treatment of steel strip and sheet, since it provides an inert atmosphere for bright annealing and does not form soot during cooling.

WITH the price of magnesium down to a more competitive level, there are signs that the motor industry is taking a second look at it. Featured in the winter issue of "This is Magnesium," is an article on the use of magnesium alloys in stressed components of Cooper Climax racing cars. A further article deals with the protection of magnesium alloys from corrosion where service conditions make it necessary, and picture features illustrate applications of magnesium in conveyor belt carriages, walkie-talkie radios, nuclear fuel element canning and commercial motor vehicle engines.

THE alloys division of Union Carbide, Ltd., has recently issued a guide to the use of alloys VL 55 and VL 55(M) in the production of S.G. iron. Union Carbide, Ltd., are the distributors in the U.K. and Commonwealth for these alloys, which were developed by Metallgesellschaft A.G. and are essentially magnesium-calcium-silicon alloys (Alloy 55(M) also contains cerium) designed to give a controlled solution of magnesium in S.G. iron. The addition of these alloys is made by a simple plunging technique, and process requirements are briefly discussed in this publication.

THE importance of an adequate undercoat of nickel to the protection afforded by nickel-chromium plating is widely recognised, and an article in *Wiggin Nickel Alloys* No. 60 describes methods of measuring the thickness of electrodeposited coatings. In the same issue an account is given of the manufacture of Integron extended surface tubing which is available in Monel and nickel for heat exchange applications involving severe corrosive attack. Other features deal with the application of nickel alloys in a variety of industries, including the chemical, electrical and metal industries. Topics of interest to the last named include heat treatment furnace equipment and the use of Monel for the lifting arms and spray piping and nozzles in a plant for the continuous pickling of steel strip.

THE central feature of the February issue of *The Magcan Tabloid*, the publication of the Magnesium Co. of Canada, Ltd., is a sketch playing on the suggestion that we are getting softer as a result of technological advances and equipment devised to assist in human advancement, the caption being "Is it possible the extensive use of light magnesium will make us too puny to withstand the rigours of the difficult life illustrated above?" The sketch features a number of goods in which magnesium is used today and the remaining pages illustrate others photographically, particularly in the automobile and tractor field.

FOR over fifteen years Electronic Instruments, Ltd., have specialised in the development and manufacture of *p*H meters for research, development, education, industrial and process control and medicine. In 1947 they produced the first direct reading *p*H meter in the U.K. Then, following the development of the Vibron, instruments capable of recording accurately *p*H changes of 0·005 were produced. At the same time new *p*H electrodes were developed, ranging from tiny ones for medical research to giants for use in industrial chemical reservoirs. A fully-coloured catalogue describing E.I.L.'s complete range of instruments has recently been produced with the title "*p*H Meters by E.I.L."

THE nickel and electrodeposition sections of the January *Nickel Bulletin* form an interesting feature of the issue. The former contains abstracts of papers presented at a symposium on the "Mechanical Properties of Intermetallic Compounds" held at Philadelphia in 1959; the four papers abstracted in the latter were read at a symposium which, held in London in 1960 under the aegis of the Institute of Metal Finishing, was concerned with recent developments in, and acceptance requirements for, nickel/chromium plating.

Of the items appearing in other sections of the issue, abstracts covering a series of papers of the corrosion problems encountered in oil- and coal-fired furnaces may perhaps be singled out as worthy of special note. The usual quarterly review of recent patent literature covers a wide field, ranging in subject matter from extraction of nickel and magnesium from ores, to an improved hair bleach, nickel-plating solutions and nickel-base high-temperature alloys.

A THIRD edition of "Noble Metal Thermocouples" by H. E. Bennett, F.I.M., has been published by Johnson Matthey. The book describes the development of the noble metal thermocouple; its applications in steelworks, foundries, and glassworks; and methods of calibration. Curves of temperature against e.m.f. are given for many types of couple incorporating alloys of the platinum group metals, and a chapter describes the chief causes of deterioration in service. A new feature of the present edition is a short section summarising the behaviour of the many thermocouple combinations that have been proposed from time to time, and recommending those most suitable for particular applications. The book is available free on application to Johnson, Matthey & Co., Ltd., 73-83 Hatton Garden, London E.C.1.

WE have received from Griffin & George (Sales) Ltd., a copy of their catalogue on volumetric and lampblown glassware, marketed under the Griffin and E-mil trade names.

Books Received

"Practical Physical Metallurgy," by R. Rawlings. 159 pp., inc. appendices and index; numerous diagrams and illustrations. London 1961. Butterworth & Co. (Publishers), Ltd. 30s. net.

"Industrial Electric Furnaces and Appliances," by V. Paschkis and J. Persson. Second edition, revised and enlarged. 607 pp., inc. appendices and index; numerous diagrams and illustrations. New York 1960. Interscience Publishers, Inc. 180s. net.

"A History of Platinum," by D. McDonald. 254 pp., inc. name and subject index; diagrams and many illustrations. London 1960. Johnson Matthey & Co., Ltd. 35s. net.

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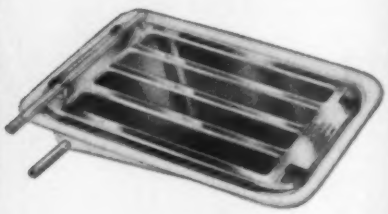
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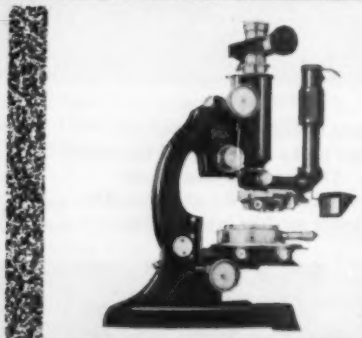
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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
APRIL, 1961 Vol. LXIII, No. 37

The Spectrophotometric Determination of Major Amounts of Cobalt in Nickel Alloys

By N. M. Silverstone and B. B. Bach, B.Sc., A.R.I.C.

The International Nickel Co., (Mond) Ltd., D. & R. Dept. Laboratory, Birmingham

A method is described for the accurate determination of major amounts of cobalt in nickel alloys. After preliminary separation of iron and chromium as hydroxides, using pyridine, the coloured complex between cobalt^{III} and ethylenediaminetetra-acetic acid is formed. The cobalt is determined spectrophotometrically and interference due to copper and nickel is eliminated.

MAJOR amounts of cobalt in nickel alloys are usually determined either titrimetrically with ferrocyanide, or gravimetrically using 1-nitroso-2-naphthol. In the titrimetric method, manganese is known to interfere, and the gravimetric method tends to be unwieldy when dealing with large amounts of cobalt. Nitroso-R-salt is used to form a coloured cobalt complex which may be measured spectrophotometrically but, owing to the high sensitivity of the reaction, very small sample weights must be used when cobalt is present as a major constituent. The work described below was carried out in response to requests for an alternative accurate method for determining large amounts of cobalt in nickel alloys.

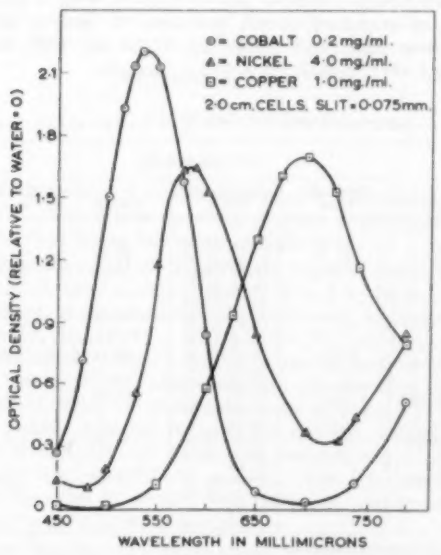

Fig. 1—Absorption spectra of cobalt, nickel and copper after pyridine separation, E.D.T.A. treatment and hydrogen peroxide oxidation.

Experimental Procedure

Welcher[1] and Williams[2] refer to the use of E.D.T.A. (ethylenediaminetetra-acetic acid) and hydrogen peroxide for the colorimetric determination of cobalt. When a faintly acid solution of a cobalt salt is heated to boiling in the presence of E.D.T.A. and hydrogen peroxide, the very stable purple-coloured cobalt^{III}/E.D.T.A. complex is formed. Other metals frequently present in nickel alloys, such as molybdenum, chromium and manganese, were examined under these conditions and it was found that only chromium gave a colour similar to that of cobalt. Attempts fully to suppress the colour due to chromium were not satisfactory and steps were therefore taken to remove this element.

In the presence of iron, chromium is precipitated by pyridine as a mixture of ferric and chromic hydroxides and, provided that sufficient iron is present, the precipitate is readily filtered. Titanium, aluminium and zirconium are also precipitated, leaving in solution cobalt, nickel, copper, manganese and molybdenum.

Spectrophotometry

Following the pyrdine separation, and treatment with E.D.T.A. and hydrogen peroxide, coloured solutions were obtained with cobalt, nickel and copper. Examination of the absorption spectra, reproduced in Fig. 1, showed that the cobalt^{III}/E.D.T.A. complex has a peak absorption at 535 μ and that at that wavelength solutions containing copper and nickel absorb light to a lesser extent.

Comparison of the absorption spectra for cobalt, nickel and copper, before and after oxidation, shown in Fig. 2, revealed that, while the absorption due to cobalt, measured at 535 μ, increased by a factor of greater than 10, there was no change in the absorption due to nickel and copper when measured at the same wavelength. Further, in a solution containing equal concentrations of cobalt, nickel and copper in the oxidised condition, the contribution by the nickel and copper to

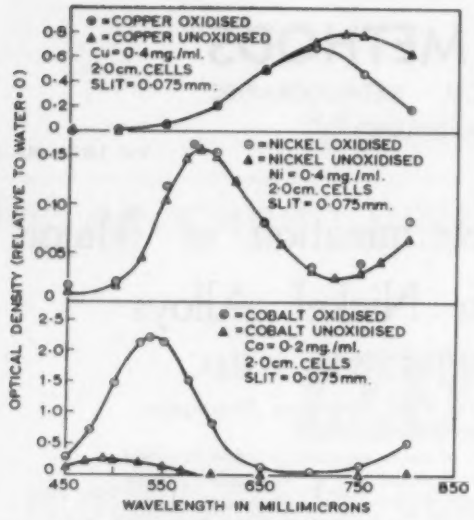

Fig. 2—Absorption spectra of cobalt, nickel and copper after pyridine separat on and E.D.T.A. treatment, with and without oxidation.

the total optical density at 535 μ is relatively small compared with that for the cobalt. Therefore, by measuring the optical density of the oxidised solution against that of the unoxidised solution, any interference due to copper and nickel is eliminated.

Colour Formation

(a) *Effect of Hydrogen Peroxide*

Incomplete oxidation occurs if insufficient hydrogen peroxide is present: it was found that 2 ml. of 100 vol. hydrogen peroxide is required to ensure complete oxidation of 8 mg. of cobalt. Excess reagent had no noticeable effect on the colour.

(b) *Effect of Boiling*

Heating just to boiling gave maximum colour formation: prolonged boiling resulted in a slight decrease.

(c) *Effect of Pyridine*

Whilst large variations in the amount of pyridine added affected colour development (increasing pyridine concentration giving decreasing optical density), the small variations experienced when using a measuring-cylinder for the additions had no significant effect.

(d) *Effect of E.D.T.A.*

Use of insufficient complexing agent led to low results, but excess reagent had no noticeable effect on colour development. 3 ml. of 10% E.D.T.A. disodium salt solution were found to be sufficient for 40 mg. of sample.

Stability of Colour

According to the literature, the cobalt^{III}/E.D.T.A. complex is very stable. This was confirmed by optical-density measurements on a series of solutions (*A*) immediately after formation of the complex, (*B*) after standing for 16 hours in the dark, and (*C*) after a further period of 8 hours in daylight (See Table I).

Results

Using the method described below, the cobalt content of a number of samples was determined. The results (see Table II), demonstrate that the method is accurate

TABLE I.—STABILITY OF COBALT^{III}/E.D.T.A. COMPLEX

Cobalt (%)	Optical Density		
	A	B	C
4·0	0·325	0·325	0·330
10·0	0·805	0·804	0·806
14·0	1·123	1·119	1·121
20·0	1·612	1·607	1·610
24·0	1·921	1·915	1·916

A—Immediately after formation of complex.
B—After 16 hours in the dark
C—After further 8 hours in daylight.

and that it gives good reproducibility, with a mean coefficient of variation of better than ± 0·3% of content, over the range 15–21% cobalt.

Recommended Procedure

Reagents

It is recommended that reagents, whenever possible, should be of AnalaR or equivalent grade.

Mixed Acids.—70 ml. hydrochloric acid (sp. gr. 1·16–1·18), 50 ml. nitric acid (sp. gr. 1·42) and 30 ml. water.

Hydrochloric Acid (sp. gr. 1·16–1·18).

Pyridine.

E.D.T.A. Disodium Salt (10%).—Dissolve 10 g. ethylenediaminetetra-acetic acid disodium salt in 100 ml. water.

Iron Solution.—Dissolve 4·0 g. pure iron in 20 ml. hydrochloric acid (sp. gr. 1·16–1·18) and dilute to 100 ml. with water.

Hydrogen Peroxide (100 vol.).

Standard Cobalt Solution 'A'.—Dissolve 1·000 g. of spectrographically pure cobalt wire in a mixture of 10 ml. nitric acid (sp. gr. 1·42) and 10 ml. hydrochloric acid (sp. gr. 1·16–1·18), under an air condenser. Cool, and make up to 250 ml. with water, in a volumetric flask. 1 ml. ≡ 2·00% cobalt on a 0·2 g. sample.

Standard Cobalt Solution 'B'.—Transfer, with a pipette, 25 ml. of standard cobalt solution 'A' into a 50 ml. volumetric flask and make up to 50 ml. with water. 1 ml. ≡ 1·00% cobalt on a 0·2 g. sample.

TABLE II.—DETERMINATION OF COBALT IN NICKEL-ALLOY SAMPLES

Sample	Cobalt (%)			
	Certificate Value	Determined Values	Average	Standard Deviation
No. 266[1]	23·4	23·48, 23·38	23·43	——
No. 233[1]	27·72	27·77, 27·66	27·72	——
Nilo K[2]	——	15·22, 15·26 15·28, 15·31 15·31, 15·35	15·28	±0·04
Nilo K	——	17·37, 17·39 17·43, 17·44 17·44, 17·47	17·42	±0·04
Nilo K	——	19·24, 19·25 19·35, 19·37 19·38, 19·40	19·33	±0·07
Nimonic 100[3]	——	17·20, 17·22 17·25, 17·25 17·30	17·26	±0·04
Nimonic 100	——	18·87, 18·91 18·93, 18·94 19·03	18·94	±0·04
Nimonic 100	——	21·09, 21·09 21·11, 21·15 21·19	21·13	±0·04

1 British Chemical Standards.
2 "Nilo K"[4]: Percentage composition—C 0·10 max., Si 0·25 max., Cu 0·25 max., Mn 0·15–0·30, Ni 29 nominal, Co 17 nominal, per cent., Fe balance.
3 "Nimonic 100"[4]: Percentage composition—C 0·20 max., Ti 1·0–2·0, Cr 10–12, Al 4·0–6·0, Mo 4·5–5·5, Si 0·5 max., Fe 2·0 max., Co 18–22, per cent., Ni balance.
4 Registered trade marks.

Method

Transfer approximately 0·2 g. of sample, accurately weighed, into a 50 ml. squat-form beaker; add 1·0 ml. of iron solution (*see Note* 1), and 5 ml. of mixed acids. Cover with a watch-glass and warm to complete dissolution. Carefully evaporate almost to dryness, cool, add 5 ml. of hydrochloric acid and warm gently to dissolve all the salts. Bring to the boil, cool, and transfer into a 100 ml. volumetric flask. Adjust the volume to about 80 ml. with water, add 15 ml. of pyridine, mix, and cool to room temperature. Make up the volume to 100 ml. with water, mix thoroughly, and allow to stand for 10–15 minutes.

Filter through a dry Whatman No. 4 filter-paper, 11·0 cm. diameter, contained in a dry filter-funnel, and collect the filtrate in a suitable, dry beaker, discarding the first few ml. of filtrate.

Measuring Solution

Transfer, with a pipette, 10·0 ml. of the filtrate into a 30 ml. tall-form beaker, add 5 ml. of E.D.T.A. disodium salt solution and 3 ml. of hydrogen peroxide. Bring to the boil, cool, transfer into a 50 ml. volumetric flask, and cool to room temperature. Make up to 50 ml. with water and mix thoroughly.

Blank Solution

Transfer, with a pipette, 10·0 ml. of the filtrate into a 50 ml. volumetric flask, add 5 ml. of E.D.T.A. disodium salt solution, make up to 50 ml. with water and mix thoroughly. Determine the optical density of the measuring solution against that of the blank solution, which is set to an optical density = 0. Preferably a Uvispek spectrophotometer is employed (*see Note* 2) using 4·0 cm. glass cells and a slit width of 0·075 mm. Measurement should be made at a wavelength of 535μ.

Calculation of Results

After converting the measured optical density to percentage cobalt, by means of the prepared calibration graph, the correct content is obtained from the equation,

$$\text{Co } \% = \frac{\text{cobalt found} \times 0{\cdot}2000}{\text{wt. of sample taken}}$$

Calibration

Known amounts of cobalt are added to the equivalent of 0·20 g. of a synthetic alloy having a composition similar to that being analysed, as follows:—

Into a series of 50 ml. squat-form beakers containing the synthetic alloy solution, pipette 8·0, 9·0, 10·0, 11·0 and 12·0 ml. of standard cobalt solution 'A', equivalent, respectively, to 16·0%, 18·0%, 20·0%, 22·0% and 24·0% of cobalt. Into a second series of beakers containing the synthetic alloy solution pipette 8·0, 9·0, 10·0 and 11·0 ml. of standard cobalt solution 'A' and to each beaker add, by means of a pipette, 1·0 ml. of standard cobalt solution 'B', to give, respectively, 17·0%, 19·0%, 21·0%, and 23·0% cobalt. Add 1 ml. of iron solution (*see Note* 1), evaporate to dryness, and treat as given above for a normal sample.

Measure the optical density as above and plot a graph of optical density against percent cobalt, to cover the range 15·0–25·0% cobalt.

Notes

Note 1. For alloys having an iron content greater than 20% the iron solution is omitted.

Note 2. Spectrophotometers other than the Uvispek may be used, but if an abridged instrument is used accuracy may suffer.

Acknowledgment

The authors are indebted to The International Nickel Co. (Mond), Ltd., for permission to publish this paper.

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1 F. J. Welcher: "The Analytical Uses of Ethylenediaminetetra-acetic Acid," New York: D. Van Nostrand Co. Inc., 1958 (see especially pp. 280-281).
2 W. J. Williams: "Analytical Chemistry of Cobalt," *Talanta*, 1958, **1**, July, 88-104.

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Creep Data

The Creep Information Centre has been established at the National Engineering Laboratory so that data on the strength of materials for use at elevated temperatures can readily be made available to designers from one source. It has been set up in response to requests from manufacturers and users of high-temperature materials, and it is hoped that it will become the national centre for information on the mechanical properties of materials for use at elevated temperatures.

Creep and rupture properties of conventional high-temperature materials are now being collected and tabulated, and some British manufacturers have already sent details of their standard materials to C.I.C. In due course, high-temperature data for British materials will be issued in an agreed form, although commercial security may restrict publication of some of the data. Later, it is hoped to extend the scheme to cover all mechanical properties of British materials for use at elevated temperatures, to collect details of testing machines and test procedures, and also to obtain information about foreign materials and equipment. Further information is given in: C.I.C. Note No. 1, available from the Laboratory at East Kilbride, Glasgow.

Electrolytic Polishing of Bismuth

By G. A. Hare, A.I.M. and H. D. Mallon, B.Sc., A.R.T.C. A.I.M.

Metallurgy Branch, Royal Military College of Science, Shrivenham.

Because of the depth of the effect of surface deformation during grinding, the production of metallographic specimens of bismuth is very difficult. The authors describe a technique involving alternate grinding and etching, followed by electrolytic polishing.

THE polishing of bismuth, particularly in the case of single crystals, is difficult due to the low hardness and to the facility with which mechanical twins form. Machining or grinding on coarse emery paper produces deformation in the surface which extends much deeper into the crystals than is the case with the harder metals. The only successful method of mechanical polishing found by the authors required prolonged polishing on fine grades of diamond followed by polish attack using magnesia powder saturated with very dilute acid ferric chloride solution. This technique gave results suitable for making measurements with polarised light, but the method is very slow and requires considerable skill to obtain reproducible results.

An attempt was made, therefore, to develop a method of electropolishing which would eliminate the prolonged grinding and give surfaces with reproducible optical properties. The solution reported by Mott and Haines[1] was tried but it was difficult to produce a polish free from surface films. Experiments using ethyl alcohol as solvent resulted in a solution containing hydrochloride acid and orthophosphoric acid and which gave good results over a wide range of concentrations. For the best results it is necessary to use apparatus of the type developed by Sykes, Hadrell, Haines and Mott,[2] where

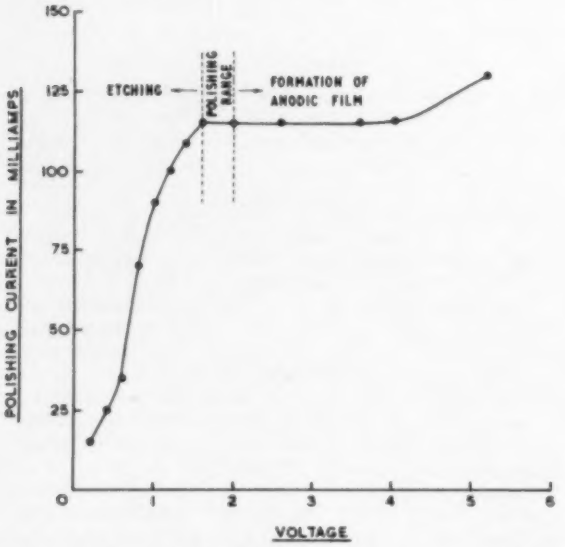

Fig. 1.—Current-voltage curve for the electrolytic polishing of bismuth using a bath temperature of 21° C. and a circular anode of 0·5 sq. cm. area

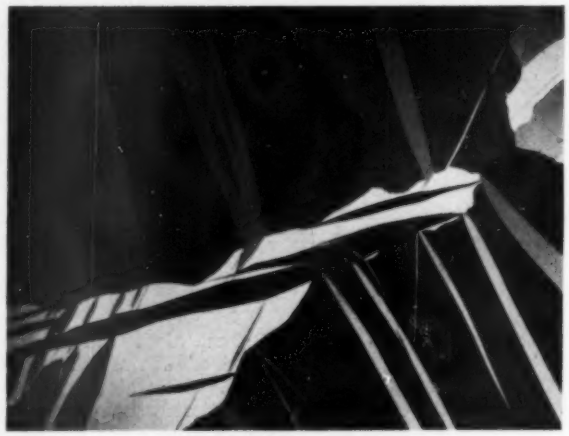

Fig. 2.—Photomicrograph of electropolished cast bismuth. Polarised light × **300**

the solution is pumped through the cathode against the anode surface. The most satisfactory solution had the following composition :—

Ethyl alcohol	10 vol.
Orthophosphoric acid (s.p. gr 1·75).	10 vol.
Conc. hydrochloric acid (sp. gr. 1·16)	3 vol.

Polishing is carried out at room temperature and, with the volume of solution used (700 ml.), cooling is unnecessary. A current-voltage curve for this solution is shown in Fig. 1, the anode current density required for polishing being 0·23 A./sq. cm. The lower part of the curve is the range where etching occurs, while the flat with constant current corresponds with the formation of an anodic film. The polishing range occurs at the onset of film formation, the polishing current being determined by the anode surface area, the rate of flow of the electrolyte and the bath composition.

In practice, precise conditions for polishing a specimen are best found by trial. Having established the polishing current, voltage control is necessary to avoid film formation on the surface, film formation and breakdown being indicated by fluctuating voltage and current. The sequence of events with increasing voltage is as follows :—

(1) Complete etching.
(2) Edge polish, centre etch.
(3) Complete polish.
(4) Edge film, centre polish.
(5) Complete film.

Starting with a machined surface, the complete technique for producing bismuth specimens suitable for optical measurements is as follows :—

(1) Grind wet with light pressure on successively finer grades of emery paper down to 600 grit.

(2) Etch in acid ferric chloride solution.

(3) Repeat wet grinding on 600 grit paper followed by ferric chloride etch until microstructure shows deformed layer has been removed.

(4) Wash in alcohol.

(5) Electropolish for a minimum time of 5 minutes.

(6) Wash in alcohol, then water, then alcohol and dry in warm air blast.

If the microstructure still shows the presence of many very thin twin bands the specimen should be reground on 600 grit paper and the electropolish repeated. A photomicrograph of bismuth prepared in this manner is shown in Fig. 2.

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1 Mott, B. W., and Haines, H. R., *J. Inst. Metals*, 1951-52, **80**, 630.
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Chemical Polishing of Lead and its Alloys

By R. C. Gifkins*

In this note the author describes the technique for obtaining a satisfactory chemical polish using the Worner and Worner reagent, comprising a mixture of glacial acetic acid and hydrogen peroxide.

IN an article in *Metallurgia*, Gregory, Bangay and Paris[1] described techniques for the polishing and etching of lead and its alloys. They mentioned the use of the Worner and Worner[2] reagent for chemical polishing, giving the composition as glacial acetic acid and 100 vol. hydrogen peroxide in the proportion of 75 : 25 ; this reagent was stated to give rise to pitting readily. The original reagent was made with the proportions of glacial acetic acid and hydrogen peroxide, 70 : 30, and our experience has been that small departures from this proportion impair its polishing properties. Usually the composition of the mixture has to be adjusted drop by drop to produce a good polish free from staining or pitting. With pure lead, an excess of hydrogen peroxide leads to matt streaks or even pits, whereas excess acetic gives a bluish etch or roughening of individual grains (i.e. a kind of macro etch).

It has recently been found that the final polish can be improved and obtained more readily, without the need for such care in the adjustment of composition, by the following method. The solution is poured rapidly over the specimen, some 50 ml. of polishing solution being poured in 3 or 4 seconds. The stream of liquid and the specimen are moved during pouring so that the liquid runs over the specimen randomly, and not according to a fixed pattern of flow lines. The specimen is rapidly washed in cold running water, rinsed in alcohol and dried in a blast of warm air. Staining during drying is minimised if the alcohol is allowed to dry from one edge of the specimen, so that the liquid interface moves across the specimen smoothly rather than contracting to several points, when small spots may result.

The process of etching and drying is repeated until a satisfactory polish has been obtained. With pure lead and some of its alloys (e.g. lead-thallium) the polish is completely free from pits ; grain boundaries are barely perceptible. With alloys, many non-metallic phases are revealed cleanly, but others tend to be left either above or below the level of the matrix and rounded to some extent at their edges. Figs. 1 and 2 show the results that

* Physical Metallurgy Section, C.S.I.R.O., Baillieu Laboratory, University of Melbourne.

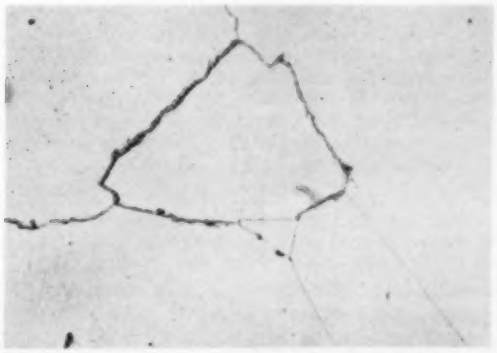

Fig. 1.—Lead–0·05% Cu–0·85% Sb alloy; cast, worked, and annealed at 200° C. Final polish in stream of Worner and Worner reagent. × 100.

Fig. 2.—As Fig. 1. × 300.

can be obtained with a fairly complex microstructure: the alloy is the same as that used for some of the illustrations to the article by Gregory *et al.* It contains 0·05% Cu, 0·85% Sb and was hammered after casting and then annealed for a few hours at 200° C. Before polishing chemically, it was ground on wet papers and on diamond pastes, finishing on a 0–1μ grade. Although it was difficult to obtain a first-rate polish for all constituents in this alloy, especially for photography, the finish was quite adequate for general visual examination. The time of polishing could be adjusted to give optimum finish to specific constituents.

REFERENCES

1 P. Gregory, A. J. Bungay and R. Paris, *Metallurgia*, 1959, **60**, 233.
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Exhibits of Metallurgical Interest at the Physical Society Exhibition

(*Continued from page 154 of the March issue*)

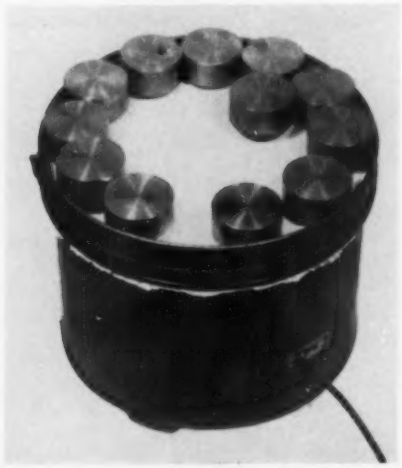
DEVELOPED in conjunction with the metals division of Imperial Chemical Industries, Ltd., and Vacuum Research, Ltd., the Young's modulus equipment exhibited by Cawkell Research & Electronics, Ltd., is designed to facilitate the measurement of the modulus of elasticity and internal damping of laboratory specimens over a wide range of temperature (20°–1,000° C.) and to a high degree of precision.

An accurately machined specimen (10 cm. long × 6 mm. diameter) is supported on needle points in an evacuated oven and excited into longitudinal oscillation in its fundamental mode. The frequency of oscillation is measured accurately and from this figure and a knowledge of the dimensions of the specimen its modulus of elasticity may be calculated. The damping capacity is obtained by removing the source of excitation and counting the number of cycles of oscillation which occur between two pre-determined amplitude levels. A direct reading of "Q," which is related to the logarithmic decrement of the specimen, is obtained.

The specimen is excited electrostatically and the signal is picked up in a similar fashion. The specimen forms part of a feed-back loop with the phase relations so adjusted that continuous oscillation occurs. The frequency is determined by the specimen. A selective amplifier is incorporated in the receiving system to reduce the effect of unwanted pick-up, such as might be caused by vibration of the apparatus, and by thermionic radiation by the specimen. A counter-chronometer is used to measure the frequency, or, as an alternative, the specimen may be energised from an accurately calibrated oscillator.

The "Q" of the specimen is presented on a series of dekatron tubes. A cathode-ray oscillator is built into the equipment for monitoring the selective amplifier output for the detection of resonance. This oscilloscope may also be used for frequency comparison against a reliable standard by means of a Lissajous' figure display, and the damped oscillation, after removal of the excitation, may be photographed from the tube screen.

A high-grade vacuum system is incorporated and uses an oil vapour diffusion pump backed by a mechanical pump. The vacuum system is tested to a leak rate better than 0·01 micron.L/sec. at a vacuum better than 0·1 micron Hg. The temperature and vacuum are accurately monitored and continuously controlled. Provision is made for the automatic isolation of the mechanical pump in the event of power supply failure.



The Nashton vibratory polisher.

Vibratory Polisher

Most metallographic polishing machines accept only a few specimens and removal of one necessitates readjustment of the machine. The Nashton vibratory polisher (Nash and Thompson, Ltd.) eliminates this problem since it can polish any number of specimens from two to eighteen in one loading. The polisher will operate with no attention and specimens can be polished overnight. This equipment is designed to reduce the labour content of specimen preparation. Specimens are placed on the abrasive surface and loaded with the weight, the vibratory motion of the table top developing a polishing action which, at the same time rotates the specimens. Specimens can be polished to a finish for electron microscope examination.

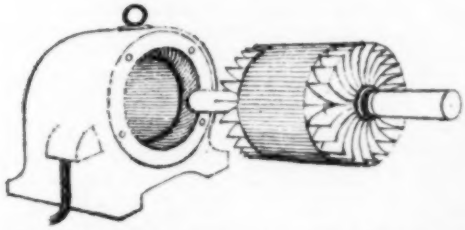
An AEI type MS7 spark-source mass spectrometer has been despatched by air to Radio Corporation of America, Princeton. Valued at over £20,000, the order was secured by AEI instrumentation division against intense competition from American manufacturers, and the equipment is the first of its kind to be supplied abroad. Other export orders in hand for the MS7 are for Holland, France, Germany, Switzerland and the U.S.S.R.: one of the two for the U.S.S.R. will be shown on the AEI stand at the British Trade Fair in Moscow.

Electric Motors & Controls 1

Most manufacturers today employ electric motive power through individual drives, which, among their many advantages, permit the right type of motor to be used for each of various types of machine. The range of motors available—each with its own characteristics–is very large, and the factory executive could well be guided in his choice by the expert views of the motor manufacturer, the installing engineer or his Electricity Board's engineer. The characteristics of the main types of motor are briefly summarised below.

Squirrel-cage Motors

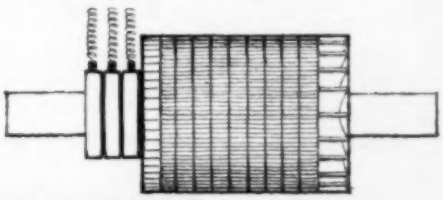
These are the most straightforward and simple in design, and are therefore relatively cheap and robust in character. They should be considered for general duties and, in conjunction with variable-speed gears or couplings, for applications requiring variable speeds, e.g. for crane drives. Small sizes can be switched direct-on-line.



The squirrel-cage motor is very suitable for individual drive of each motion of single-purpose machine tools where the motor horsepower can be precisely specified. It is suitable for driving pumps, fans, lifting hoists and woodworking machines. Textile machinery represents another field of use.

Slip-ring Motors

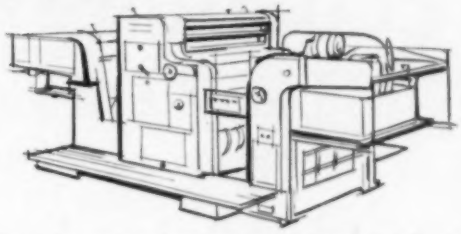
The chief advantage of the slip-ring motor is a very low starting current for a given torque, e.g. full-load torque at starting with a current about 10% above full-load current. This makes it suitable for applications requiring a prolonged starting period with a



load of high inertia. It also permits of speed variation below synchronous speed, though with some loss of efficiency. Typical applications include fans, pumps, heavy lathes, grinders and boring mills, as well as calendering machines, cable-laying-up machines and mine hoists.

Three-phase A.C. Commutator Motors

The main characteristic of this type is variable-speed with uniform and gradual acceleration and good efficiency over the speed range. Paper manufacture provides excellent examples of its use, e.g. in paper-making, reeling, cutting, calendering, coating and drying.



A.C. commutator motors are recommended for mechanised bakeries and for cranes and hoists where very slow speeds are frequently needed.

Synchronous Motors

These are constant-speed motors. One particular advantage is that they can be operated at unity or even at leading power factor to correct a system suffering from lagging power factor, and perhaps so qualify for a reduction in the electricity bill. Pump and compressor drives are typical uses to which they can be put. They are also used in motor-generator sets.

Single-phase A.C. Motors

In general, single-phase motors are used in light industries for drives not requiring more than about five horsepower or where a three-phase supply is not available. While their use is mainly limited to work of a light nature, they do fill a need in such duties as sewing-machine drives, portable hand tools, window opening and closing gear, etc.

Direct Current Motors

For a completely unfettered performance where wide ranges of speed variation, high rates of acceleration and powerful dynamic braking are all-important, the D.C. motor is unrivalled. This means in effect the installation of an A.C.-D.C. motor-generator set or rectifier to give the necessary supply, but the increased cost may well be compensated by the improvement in productivity. When variable voltage is applied to the armature, a wider speed range is obtainable than with any other type of motor. Typical applications of the D.C. motor are: cranes, haulage and tippler equipment, certain machine tools requiring a large speed range and smooth acceleration, high-speed printing and steelworks drives.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. TEMple Bar 9434.

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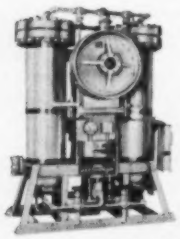

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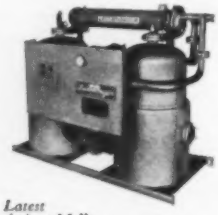

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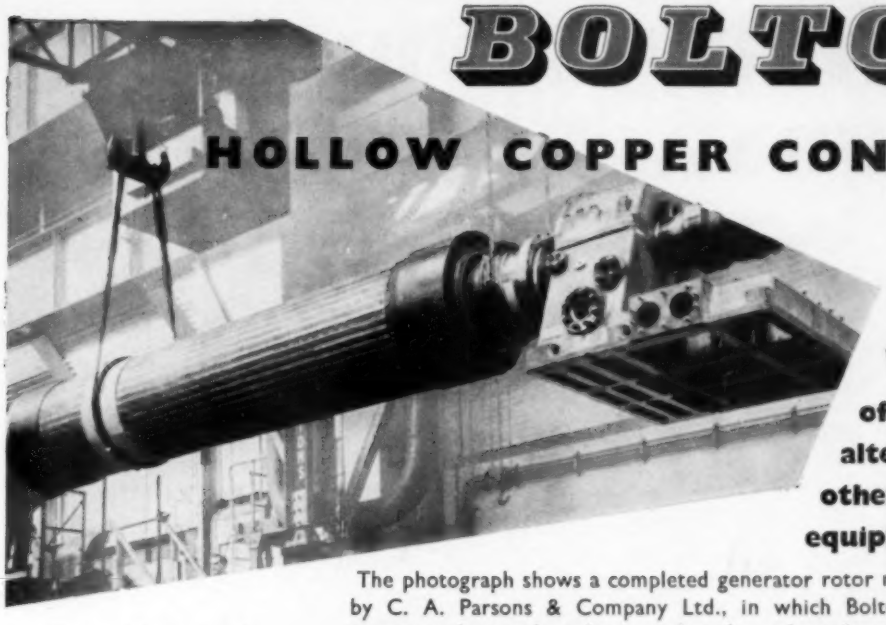

Photograph by courtesy of C. A. Parsons & Co. Ltd.,

The photograph shows a completed generator rotor manufactured by C. A. Parsons & Company Ltd., in which Bolton's hollow copper conductors have been used in the end windings. The rotor is being removed from the high speed generator which is part of a 200 MW cross-compound turbo-generator for the Richard L. Hearn generating station, Toronto, Canada.

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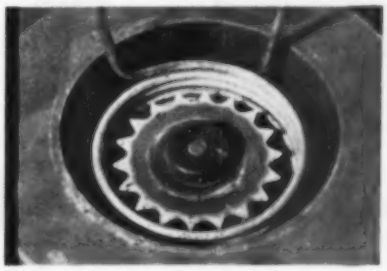

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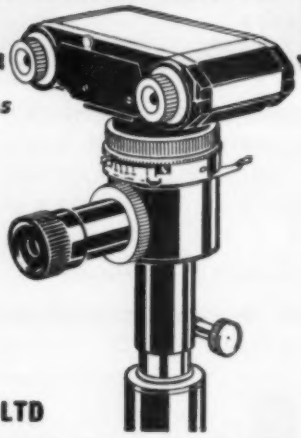

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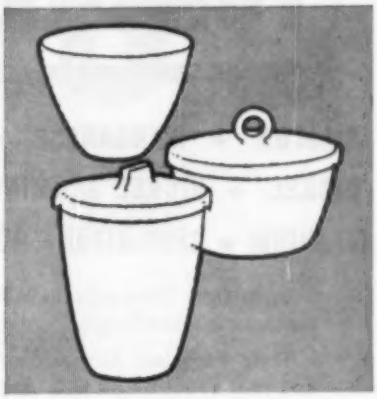

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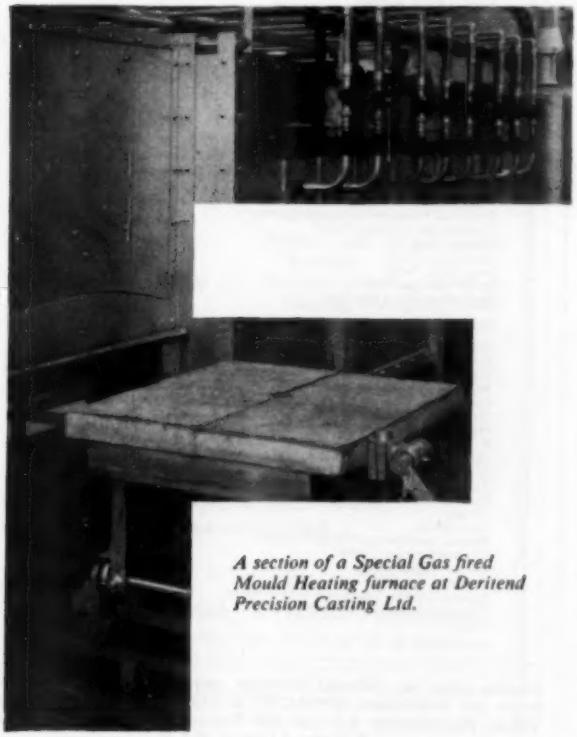

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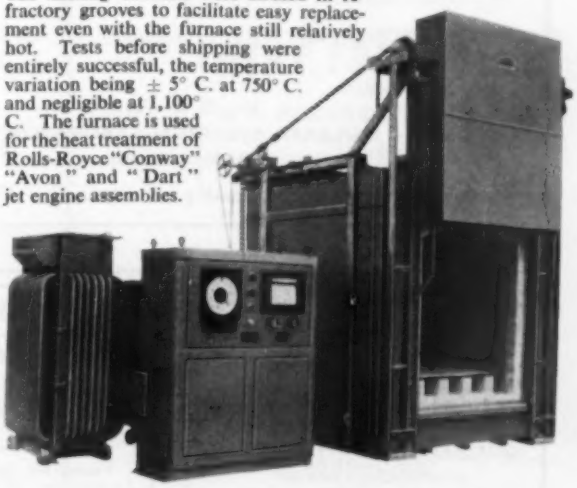

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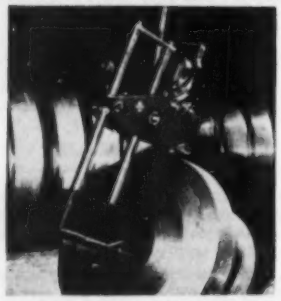

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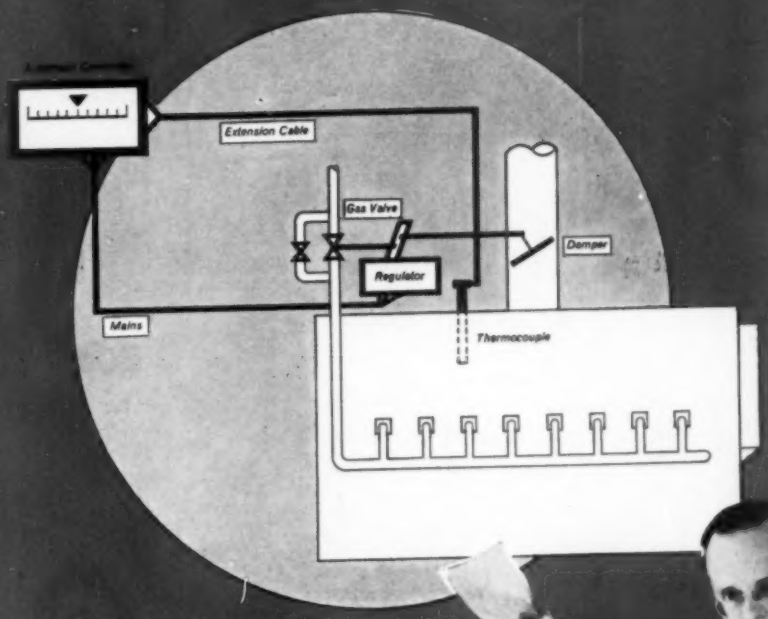

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Sales Manager of the Temperature Measurement and Control Division is continually dealing with control schemes for every type of industrial furnace and whose wide experience is available for all enquiries.

Gas Saving of up to 22%

One of the simplest—yet most effective systems of control for a natural draught gas-fired furnace is shown above. Good temperature control with a considerable degree of control of both gas/air ratio and furnace pressure is provided with this scheme.

Gas savings of up to 22% with increased throughput of up to 52% have been authenticated with the system as compared with manual control.

Electroflo

Meters & Controls

Temperature Measurement & Control Division of

ELECTROFLO METERS COMPANY LIMITED

Head Office: Abbey Road, Park Royal, London N.W.10 *Telephone:* Elgar 7661 (5 lines)

Telegrams and Cables: Effometa, London, Telex. *Telex No.* 3-8196

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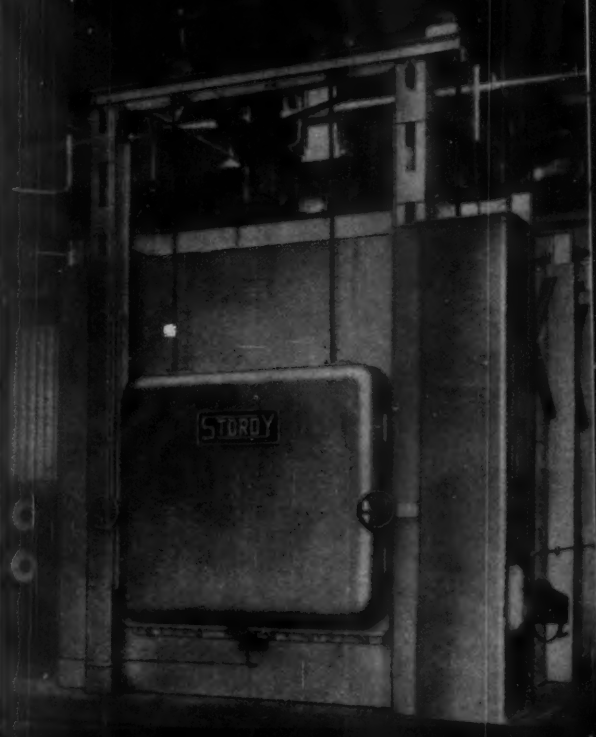
STORDY build

HEAT TREATMENT FURNACES

Stordy heat treatment furnaces include batch, pit and continuous types, heated by oil, gas or electricity, with indirect firing when required. The Stordy system of forced air circulation provides rapid heating-up rates and uniform heating throughout the chamber with maximum fuel economy,

Stordy plant includes material handling equipment—charging and discharging machines, conveyors, transfer tables, loading and unloading racks.

Illustration: Electrically heated, air circulated batch-type furnace for aluminium. Working temperature 600°C. Heated length 205' 0".



STORDY ENGINEERING LIMITED

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